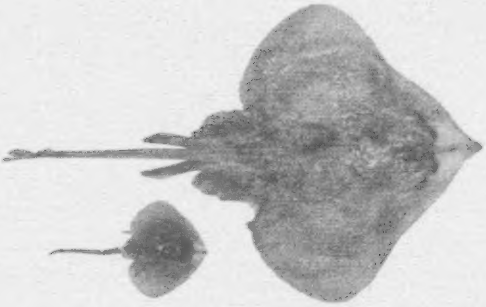
COSEWIC
Assessment and Status Report

on the

Smooth Skate
Malacoraja senta

Hopedale Channel population
Funk Island Deep population
Nose of the Grand Bank population
Laurentian-Scotian population

in Canada



Hopedale Channel population - DATA DEFICIENT
Funk Island Deep population - ENDANGERED
Nose of the Grand Bank population - DATA DEFICIENT
Laurentian-Scotian population - SPECIAL CONCERN
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2012. COSEWIC assessment and status report on the Smooth Skate *Malacoraja senta* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xix + 77 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Production note:
COSEWIC would like to acknowledge David Kulka for writing the status report on Smooth Skate *Malacoraja senta* in Canada, prepared under contract with Environment Canada. This report was overseen and edited by John Reynolds, Co-chair of the COSEWIC Marine Fishes Specialist Subcommittee, with the support of Howard Powles, Craig Purchase, and Scott Wallace from the Marine Fishes Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Raie à queue de velours (*Malacoraja senta*) au Canada.

Cover illustration/photo:
Smooth Skate — Photo provided with permission by DFO, Newfoundland, Marine Species at Risk.

©Her Majesty the Queen in Right of Canada, 2012.
Catalogue No. CW69-14/655-2012E-PDF
ISBN 978-1-100-20719-3

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – May 2012

Common name
Smooth Skate - Hopedale Channel population

Scientific name
Malacoraja senta

Status
Data Deficient

Reason for designation
This designatable unit is at the northern limit of this species' range, and surveys here have been sporadic (14 surveys since 1977, not always complete). Although available information suggests that the extent of occurrence has fluctuated over time, with an increase since 1990, and that the number of mature individuals seems to have fluctuated without trend, perhaps increasing in recent years, inferences are hampered by the paucity of data and by changes in sampling gear. High data uncertainty therefore prevents status determination. There are no targeted fisheries for this species, and bycatches appear to have been low since the mid-1990s.

Occurrence
Newfoundland and Labrador, Atlantic Ocean

Status history
Species considered in May 2012 and placed in the Data Deficient category.

Assessment Summary – May 2012

Common name
Smooth Skate - Funk Island Deep population

Scientific name
Malacoraja senta

Status
Endangered

Reason for designation
There have been steep declines in abundance of both adult and young individuals in this designatable unit (DU) since the early 1980s. While numbers of adults appear to have increased over the past five years, the overall abundance remains very low. These trends in abundance are matched by strong reductions in area of occupancy. There are no targeted fisheries for this species, and bycatches have been declining since the early 1980s. However, it has continued to decline even in areas with low trawling intensity.

Occurrence
Newfoundland and Labrador, Atlantic Ocean

Status history
Designated Endangered in May 2012.

Assessment Summary – May 2012

Common name
Smooth Skate - Nose of the Grand Bank population

Scientific name
Malacoraja senta

Status
Data Deficient

Reason for designation
This designatable unit (DU) is a minor part (1.9%) of the global distribution of this species. Fish were encountered in only 11 of 37 years of surveys, with an average number of fish/year of 0.7. Too little is known to assess status in this DU, including abundance and area of occupancy.

Occurrence
Newfoundland and Labrador, Atlantic Ocean

Status history
Species considered in May 2012 and placed in the Data Deficient category.

Assessment Summary – May 2012

Common name
Smooth Skate - Laurentian-Scotian population

Scientific name
Malacoraja senta

Status
Special Concern

Reason for designation
This designatable unit (DU) historically accounts for 90% of the species' estimated abundance in Canada and 70% of the Canadian range. Trends vary among regions within this large DU, but overall numbers have likely been increasing in recent years. However, on the Scotian Shelf, which used to be the centre of abundance for this species, both abundance and area of occupancy have declined steeply since the 1970s, and numbers remain low. It is not clear what has caused the trends to differ among areas. There are no directed fisheries for this species, and bycatches have been low for the past decade in this DU. There have been recent increases in natural mortality of adults in the southern Gulf of St. Lawrence.

Occurrence
Quebec, New Brunswick, Prince Edward Island, Nova Scotia, Atlantic Ocean

Status history
Designated Special Concern in May 2012.

COSEWIC
Executive Summary

Smooth Skate
Malacoraja senta

Hopedale Channel population
Funk Island Deep population
Nose of the Grand Bank population
Laurentian-Scotian population

Wildlife Species Description

The Smooth Skate, *Malacoraja senta,* is endemic to the northwest Atlantic (Canada and USA). It is one of the smallest species of skate in region, with a longer tail relative to its body length than other species.

Distribution

Smooth Skate are found from the mid-Labrador coast (Hopedale Channel) to southern Georges Bank south of Cape Cod. In Canada, they are found from the mid-Labrador coast to Georges Bank (Canadian sector). They have a disjunct distribution, and they are considered to form four designatable units (DUs) in Canadian waters: Hopedale Channel, Funk Island Deep, Nose of the Grand Bank, and Laurentian-Scotian. The area of occupancy and abundance of this species in Canadian waters have increased in some areas (e.g. parts of the Laurentian-Scotian DU) and declined precipitously in others (e.g. Funk Island Deep).

Habitat

These fish live on the sea bottom and prefer soft mud and clay substrates. They are found over a fairly wide range of depths although this is narrower at specific latitudes. The shallowest/deepest records of this species are 25/1436 m. The densest concentrations occur between 150 and 550 m. The fish are found over a relatively narrow range of temperatures, avoiding the coldest areas. The densest concentrations, comprising 90% of survey occurrences, were found where bottom temperature was between 3 and 10° C.

Biology

Like most skates, Smooth Skate grow relatively slowly, are slow to reproduce (40-100 large egg capsules per year) and live a relatively long time. Female average length at maturity is 47 cm (11 years) and individuals rarely exceed 65 cm. Little is known about their predators but it is likely that their egg capsules are preyed upon by gastropods, whereas adults may be eaten by marine mammals such as Grey Seals (*Halichoerus grypus*). Their diet is primarily composed of invertebrates whereas older individuals prey on fishes as well.

Population Sizes and Trends

In Canadian waters, minimum abundance estimates for recent years (2007-2010), based on research vessel surveys, are 43.5 million, including 6.2 million adults. The centre of abundance is around the Laurentian Channel and surrounding areas. By proposed DU, recent adult minimum abundance is: Hopedale Channel – 152,000, Funk Island Deep – 320,000 (about 7% of the abundance during the peak in the 1970s), Laurentian-Scotian – 5,704,000, and Nose of the Grand Bank – unknown. Because the catchability of skates to survey trawls is thought to be low, actual abundance is likely substantially greater than these estimates.

Some areas have seen precipitous declines in population abundance. For example, mature Smooth Skate in the Funk Island Deep DU declined by 94% from 1977 to 1995 but have increased recently. Other areas typically showed smaller declines or increases in numbers of mature individuals and little change or increases in numbers of immature individuals. Overall, the populations have been increasing over the past decade.

Threats and Limiting Factors

Smooth Skate are not a targeted commercial species. Fishery bycatch in recent years has been relatively low and incidental catches in Canadian waters have declined since the mid-1990s. It is unknown whether mortality due to bycatch threatens their recovery and persistence, although fishing mortality is low. Although most individuals are discarded, their subsequent survival is unknown. Increased natural mortality may be a limiting factor in some areas.

Protection and Status

The IUCN has listed Smooth Skate as “Endangered” on the Red List, a global assessment of risk of extinction (Sulikowski *et al.* 2004). In the United States, there is currently a ban on landing this species due to population decline although the species is presently considered as “not overfished” (Miller *et al.* 2009, NOAA/NMFS 2009). In Canada Smooth Skate do not currently receive species-specific fishery management measures.

TECHNICAL SUMMARY – Hopedale Channel Population

Malacoraja senta

Smooth Skate (Hopedale Channel population) Raie à queue de velours (Population du chenal Hopedale)

Range of occurrence in Canada: Newfoundland and Labrador, Atlantic Ocean (Hopedale Channel, Labrador Shelf)

Demographic Information

Generation time (average age of parents in the population) *Based on approximation for rate of natural mortality, which is probably an underestimate compared to pre-exploitation times.*	~ 16 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	No apparent trend
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	N/A
Are there extreme fluctuations in number of mature individuals?	Probably not

Extent and Occupancy Information

Estimated extent of occurrence	11,600 km²
Index of area of occupancy (IAO)	~ 7,000 km²
Is the total population severely fragmented?	No
Number of locations* *The main threats are bycatch mortality in various fisheries under different management regimes.*	Multiple, but exact number unclear.
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	Unknown
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

---

* See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Demographic Information

Generation time (average age of parents in the population) Based on approximation for rate of natural mortality, which is probably an underestimate compared to pre-exploitation times.	~ 16 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	No apparent trend
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	N/A
Are there extreme fluctuations in number of mature individuals?	Probably not

Extent and Occupancy Information

Estimated extent of occurrence	11,600 km²
Index of area of occupancy (IAO)	~ 7,000 km²
Is the total population severely fragmented?	No
Number of locations* The main threats are bycatch mortality in various fisheries under different management regimes.	Multiple, but exact number unclear.
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	Unknown
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
1	>152,000
Total	>152,000

---

* See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not available

Threats (actual or imminent, to populations or habitats)

There are no directed fisheries for this species. The primary threat is assumed to be bycatches in bottom fisheries that target other species. Estimated current catches are relatively low.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? The population is isolated and there appears to be no possibility of rescue.	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Data Deficient (May 2012)

Status and Reasons for Designation

Status: Data Deficient	**Alpha-numeric code:** Not applicable
Reasons for designation: This designatable unit is at the northern limit of this species' range, and surveys here have been sporadic (14 surveys since 1977, not always complete). Although available information suggests that the extent of occurrence has fluctuated over time, with an increase since 1990, and that the number of mature individuals seems to have fluctuated without trend, perhaps increasing in recent years, inferences are hampered by the paucity of data and by changes in sampling gear. High data uncertainty therefore prevents status determination. There are no targeted fisheries for this species, and bycatches appear to have been low since the mid-1990s.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable.
Criterion D (Very Small or Restricted Total Population): Not applicable
Criterion E (Quantitative Analysis): Not undertaken.

TECHNICAL SUMMARY – Funk Island Deep Population

Malacoraja senta

Smooth Skate (Funk Island Deep population) Raie à queue de velours (Population de la fosse de l'île Funk)

Range of occurrence in Canada: Newfoundland and Labrador, Atlantic Ocean (northeast Newfoundland Shelf)

Demographic Information

Generation time (average age of parents in the population) Based on approximation for rate of natural mortality, and probably underestimated compared to pre-exploitation times.	~ 16 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. 1977 – 1994 (1.1 generations) 1995 – 2009 (0.9 generations) *An overall decline of >80% over two generations is inferred from surveys, taking gear change into account. A similar rate of decline can be inferred from changes in area of occupancy.*	- 94% + 166% (still <20% of peak abundance in 1970s)
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of mature individuals?	Unclear

Extent and Occupancy Information

Estimated extent of occurrence	106,400 km²
Index of area of occupancy (IAO) *Calculated from the proportion of DFO groundfish survey catches of this species (design weighted area of occupancy)*	13,500 km²
Is the total population severely fragmented?	Unknown
Number of locations* *The main threats are bycatch mortality in various fisheries under different management regimes.*	Multiple, but exact number unclear.
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Yes
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Yes
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No

---

* See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	Unknown
Are there extreme fluctuations in extent of occurrence?	Unlikely
Are there extreme fluctuations in index of area of occupancy?	No

Extent and Occupancy Information

Estimated extent of occurrence	106,400 km²
Index of area of occupancy (IAO) Calculated from the proportion of DFO groundfish survey catches of this species (design weighted area of occupancy)	13,500 km²
Is the total population severely fragmented?	Unknown
Number of locations* The main threats are bycatch mortality in various fisheries under different management regimes.	Multiple, but exact number unclear.
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Yes
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Yes
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	Unknown
Are there extreme fluctuations in extent of occurrence?	Unlikely
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	**N Mature Individuals**
1	>320,000
Total	>320,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not available

Threats (actual or imminent, to populations or habitats)

There are no directed fisheries for this species. The primary threat is assumed to be bycatches in bottom fisheries that target other species. Estimated current catches are relatively low.

---

* See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? The population is isolated and there appears to be no possibility of rescue.	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Unknown
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Endangered (May 2012)

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** A2bc
Reasons for designation: There have been steep declines in abundance of both adult and young individuals in this designatable unit (DU) since the early 1980s. Although numbers of adults appear to have increased over the past five years, the overall abundance remains very low. These trends in abundance are matched by strong reductions in area of occupancy. There are no targeted fisheries for this species, and bycatches have been declining since the early 1980s. However, it has continued to decline even in areas with low trawling intensity.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): A1 does not apply as the causes of the reduction are not clearly reversible, nor understood, and there is no evidence that they have ceased. While precise calculations of decline rates under A2b are precluded by a change in survey gear during the time series, there is strong evidence from survey indices that declines have been greater than 50%. A2c also applies, as area of occupancy has declined by about 80% in 2 generations.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the extent of occurrence > 20,000 km^2 and the area of occupancy > 2,000 km^2.
Criterion C (Small and Declining Number of Mature Individuals): Does not apply because there are more than 10,000 mature individuals.
Criterion D (Very Small or Restricted Total Population): Does not apply because there are more than 1,000 individuals, the area of occupancy is greater than 20 km^2, and there are more than 5 locations.
Criterion E (Quantitative Analysis): Not available

TECHNICAL SUMMARY – Nose of the Grand Bank Population

Malacoraja senta
Smooth Skate (Nose of the Grand Bank population) Raie à queue de velours (Population du nez des Grands bancs)
Range of occurrence in Canada: Newfoundland, Atlantic Ocean (very small area of the northeast Grand Bank, most of rest of population is outside Canada)

Demographic Information

Generation time (average age of parents in the population) *Based on approximation for rate of natural mortality, and probably underestimated compared to pre-exploitation times.*	~ 16 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of mature individuals?	Unlikely

Extent and Occupancy Information

Estimated extent of occurrence	1,000 km²
Index of area of occupancy (IAO) *Calculated from the proportion of DFO groundfish survey catches of this species (design weighted area of occupancy)*	<1,000 km²
Is the total population severely fragmented?	Unknown
Number of locations*	Unknown
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Unknown
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of populations?	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	Unknown
Are there extreme fluctuations in number of locations*?	Unknown
Are there extreme fluctuations in extent of occurrence?	Unknown
Are there extreme fluctuations in index of area of occupancy?	Unknown

---

* See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Number of Mature Individuals (in each population)

Population	N Mature Individuals
	Unknown, small
Total	Unknown, small

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not available

Threats (actual or imminent, to populations or habitats)

There are no targeted fisheries for this species. The primary threat is assumed to be bycatch mortality from bottom fisheries that target other species, though bycatches are currently relatively low.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)?	
Is immigration known or possible?	Possible
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Unknown
Is rescue from outside populations likely?	Unknown

Current Status

COSEWIC: Data Deficient (May 2012)

Status and Reasons for Designation

Status: Data Deficient	**Alpha-numeric code:** Not applicable.
Reasons for designation: This designatable unit (DU) is a minor part (1.9%) of the global distribution of this species. Fish were encountered in only 11 of 37 years of surveys, with an average number of fish/year of 0.7. Too little is known to assess status in this DU, including abundance and area of occupancy.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable.

Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable.

Criterion C (Small and Declining Number of Mature Individuals): Not applicable.

Criterion D (Very Small or Restricted Total Population): Not applicable.

Criterion E (Quantitative Analysis): Not applicable.

TECHNICAL SUMMARY – Laurentian-Scotian Population

Malacoraja senta
Smooth Skate (Laurentian-Scotian population)

Raie à queue de velours (Population laurentienne et du plateau néo-écossais)

Range of occurrence in Canada: Prince Edward Island, Nova Scotia, New Brunswick, Quebec, Atlantic Ocean (Grand Banks, Scotian Shelf, Bay of Fundy, Georges Bank)

Demographic Information

Generation time (average age of parents in the population) *Based on approximation for rate of natural mortality, and probably underestimated compared to pre-exploitation times.*	~ 16 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? *Trends vary among regions, but overall numbers do not show downward trend.*	No
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	
Div. 3LNOPs (Grand Banks) (1975-1995) • *% change (25 years, 1.3 generations)*	- 42%
Div. 3LNOPs (Grand Banks) (1996-2010) • *% change (14 years, 0.9 generations)*	+ 96%
Div. 4RS (Northern Gulf of St. Lawrence) (1991-2010) • *% change (19 years, 1.2 generations)*	+ 84%
Div. 4T (Southern Gulf of St. Lawrence) (1971-2010) • *% change (39 years, 2.4 generations)*	- 65%
Div. 4VWX (Scotian Shelf) (1970-2010) • *% change (40 years, 2.5 generations)*	- 80%
Div. 5Z (Georges Bank) (1987-2010) • % change over time period observed (23 years, 1.4 generations)	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	283,000 km²
Index of area of occupancy (IAO) *Calculated from the proportion of DFO groundfish survey catches of this species (design weighted area of occupancy)*	120,000 km²
Is the total population severely fragmented?	Unknown
Number of locations* *The main threats are bycatch mortality in various fisheries under different management regimes over a large area.*	Multiple, but exact number unclear.
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	Probably not
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	Mixed, according to region
Is there an [observed, inferred, or projected] continuing decline in number of populations?	No trend
Is there an [observed, inferred, or projected] continuing decline in number of locations*?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	Unknown
Are there extreme fluctuations in number of populations?	Unknown
Are there extreme fluctuations in number of locations*?	Probably not
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
1	>5,700,000
Total	>5,700,000

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not available

Threats (actual or imminent, to populations or habitats)

There are no targeted fisheries for this species. The primary threat is bycatch mortality from bottom fisheries that target other species, as well as predation in the south (e.g. southern Gulf of St. Lawrence).

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? USA: Fish in US waters are considered at a low but stable abundance by NMFS.	
Is immigration known or possible?	Possible
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Unknown
Is rescue from outside populations likely?	Unknown

---

* See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Current Status

COSEWIC: Special Concern (May 2012)

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** Not applicable
Reasons for designation: This designatable unit (DU) historically accounts for 90% of the species' estimated abundance in Canada and 70% of the Canadian range. Trends vary among regions within this large DU, but overall numbers have likely been increasing in recent years. However, on the Scotian Shelf, which used to be the centre of abundance for this species, both abundance and area of occupancy have declined steeply since the 1970s, and numbers remain low. It is not clear what has caused the trends to differ among areas. There are no directed fisheries for this species, and bycatches have been low for the past decade in this DU. There have been recent increases in natural mortality of adults in the southern Gulf of St. Lawrence.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not met as declines in some areas are partially offset by increases in others.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not apply because the extent of occurrence greatly exceeds 20,000 km² and the area of occupancy greatly exceeds 2,000 km².
Criterion C (Small and Declining Number of Mature Individuals): Does not apply because there are far more than 10,000 mature individuals.
Criterion D (Very Small or Restricted Total Population): Does not apply because the number of mature individuals greatly exceeds 1,000, the area of occupancy greatly exceeds 20 km², and there are more than 5 locations.
Criterion E (Quantitative Analysis): Not available.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2012)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada — Environnement Canada
Canadian Wildlife Service — Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Smooth Skate
Malacoraja senta

Hopedale Channel population
Funk Island Deep population
Nose of the Grand Bank population
Laurentian-Scotian population

in Canada

2012

TABLE OF CONTENTS

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE 8
  Name and Classification 8
  Morphological Description 8
  Population Spatial Structure and Variability 9
  Designatable Units 14
  Special Significance of the Species 14
DISTRIBUTION 14
  Global Range 14
  Canadian Range 15
  Search Effort 16
  Distribution Mapping and Area of Occupancy 16
HABITAT 36
  Habitat Requirements 36
  Habitat Trends 37
BIOLOGY 37
  Life Cycle and Reproduction 37
  Generation Time 38
  Predation 38
  Physiology and Adaptability 39
  Dispersal and Migration 39
  Interspecific Interactions 39
POPULATION SIZES AND TRENDS 40
  Sampling Effort and Methods 40
  Abundance 44
  Fluctuations and Trends 45
  Rescue Effect 63
THREATS AND LIMITING FACTORS 63
  Temperature 63
  Predation 63
  Fishery bycatch 63
PROTECTION AND STATUS 70
ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED 71
  Authorities Consulted 71
INFORMATION SOURCES 71
BIOGRAPHICAL SUMMARY OF REPORT WRITER 77

List of Figures

Figure 1a. Male Smooth Skate taken from the Funk Island Deep. Inset – recently hatched 12 cm specimen. Note white markings on the tail indicated by the arrows. 8
Figure 1b. Drawing of Smooth Skate highlighting morphometric attributes used to differentiate it from other species (after Sulak *et al.* 2009). 9

Figure 2a. Upper - global distribution of the genus *Malacoraja* and Smooth Skate, *M. senta*. Within the red squares, the species is restricted to portions of the continental shelf. Lower - Distribution of Smooth Skate catches in Canadian and US trawl surveys. Colour surface denotes density level of captures. Red lines and labels delineate the proposed DUs. See Figure 2c for the 200-mile limit and the Canada/USA border. 10

Figure 2b. Bathymetry and geographic areas referred to in this document. Blue areas comprise the continental shelf and upper slope out to a bottom depth of 1000 m. 11

Figure 2c. Distribution of sampling effort from Canadian and US trawl surveys from 1970-2009. Coloured dots show the DFO Regional and USA survey sets: green-NL. blue-Quebec, teal-Gulf, red-Maritimes, purple-USA................ 11

Figure 3. Distribution of Smooth Skate for the various DUs over their range with respect to temperature and depth during 1971-2005 (after Kulka *et al.* 2006). GoM refers to the Gulf of Maine in the Laurentian-Scotian DU..... 12

Figure 4. Long-term water temperature observations for the Grand Banks, Station "27" near the Avalon Peninsula, Newfoundland. 13

Figure 5. Growth curves for Smooth Skates. Scatterplot of total length at age for males (grey triangle) and females (white circle) are fitted with a traditional three-parameter von Bertalanffy growth curve. Growth models from previously published studies from other geographic regions are overlaid (after McPhie and Campana 2009). 13

Figure 6a. Distribution of Smooth Skate in the waters off Newfoundland and Labrador (cumulative area from 1971-2009). Grey areas denote areas sampled but with no catches, green are low catches grading to red with high catches expressed in mean number per tow. The Flemish Cap is not fully illustrated as nearly all of that area occurs outside the 200-mile limit of Canada. 19

Figure 6b. Distribution of Smooth Skate in the waters off Newfoundland and Labrador for combined spring and fall surveys by five-year intervals. Grey area denotes areas sampled but with no catches, green low catches grading to red, high catches (see Figure 6a for scale). Area sampled in 1971 is incomplete. 20

Figure 6b cont. Distribution of Smooth Skate in the waters off Newfoundland and Labrador for combined spring and fall surveys by five-year intervals. Grey areas denote areas sampled but with no catches, green low catches grading to red, high catches (see Figure 6a for scale). 21

Figure 7. Change in area of occupancy of the Funk Island Deep DU (Div. 2J3K and northern 3L). The red line is the 3-year running average. 22

Figure 8. Change in area of occupancy of the Grand Banks portion (Div. 3LNOPs) of the Laurentian-Scotian DU. The red line is the 3-year running average. . 23

Figure 9a. Distribution of Smooth Skate in the northern Gulf of St. Lawrence part of the Laurentian-Scotian DU, based on *Gadus Atlantica* survey 1978-1994. See Figure 9b for legend with colour codes. 24

Figure 9b. Distribution of Smooth Skate in the northern Gulf of St. Lawrence part of the Laurentian-Scotian DU, based on the *Lady Hammond* survey. 25
Figure 9c. Distribution of Smooth Skate in the northern Gulf of St. Lawrence part of the Laurentian-Scotian DU based on the *Teleost* survey......................... 26
Figure 10. Change in area of occupancy (DWAO) of the northern Gulf of St. Lawrence portion of the Laurentian-Scotian DU based on the *Teleost* survey equivalents. Top panel shows all fish sizes combined and the bottom shows adults and juveniles separately....................................... 27
Figure 11a. Distribution of Smooth Skate in the southern Gulf of St. Lawrence part of the Laurentian-Scotian DU.. 28
Figure 11b. Distribution of Smooth Skate in the southern Gulf of St. Lawrence part of the Laurentian-Scotian DU by stage. 29
Figure 12. Change in area of occupancy (DWAO) of the southern Gulf of St. Lawrence portion of the Laurentian-Scotian DU. The red line is the 3-year running average... 30
Figure 13. Distribution of Smooth Skate on the Scotian Shelf, part of the Laurentian-Scotian DU, based on summer surveys, 1970-2010, by decade. Dots represent the number of fish caught per tow.. 31
Figure 14. Design-weighted area of occupancy of Smooth Skate for the eastern Scotian Shelf, part of the Laurentian-Scotian DU (Div. 4VW portion). The red line is the 3-year running average. 32
Figure 15. Design weighted area of occupancy of Smooth Skate for the western Scotian Shelf (Div. 4X), part of the Laurentian-Scotian DU. The red line is the 3-year running average... 33
Figure 16. Distribution of Smooth Skate on the Gulf of Maine and Georges Bank, 1963-2009, based on US surveys. This area straddles the Canada/USA jurisdictions. 34
Figure 17. Area of occupancy of Smooth Skates in Div. 5Z on the Canadian portion of Georges Bank. The red line is the 3-year running average................. 35
Figure 18a. Relative abundance of Smooth Skate of all sizes from the Hopedale Channel DU. Solid line is a three-year running average. The break in the solid line divides Engel from Campelen estimates.................................. 46
Figure 18b. Mean number per tow of Smooth Skate juveniles (a) and adults (b) from the Hopedale Channel DU. Error bars represent upper and lower 95% confidence limits. The grey bar divides Engel from Campelen estimates. 47
Figure 19a. Relative abundance of Smooth Skate from the Funk Island Deep DU. The break divides Engel from Campelen estimates....................................... 48

Figure 19b. Mean number per tow of Smooth Skate juveniles (top row), adults (middle row) and all sizes combined (bottom row) from the Funk Island Deep DU. Error bars represent 2 SD. The grey bar divides Engel from Campelen estimates. During the 2010 surveys, fish were not measured, thus juveniles and adults are not distinguished for that year. Ln transformed data are plotted for two periods when the different survey gears were used. 49

Figure 20a. Relative abundance of Smooth Skate from the Laurentian-Scotian DU, southwest Grand Banks Region. The solid line is the 3-year running average. The break in the solid line divides Engel from Campelen estimates. 51

Figure 20b. Mean number per tow of Smooth Skate juveniles, adults and all sizes combined from the Laurentian-Scotian DU (southwest Grand Banks). Error bars represent 2 SD. The grey bar divides Engel from Campelen estimates. During the 2010 surveys, fish were not measured, thus juveniles and adults are not distinguished for that year. Ln transformed data are plotted for two periods when the different survey gears were used. 52

Figure 21a. Catch rates in the northern Gulf of St. Lawrence (Div. 4R and 3Pn) for Smooth Skate in the winter *Gadus Atlantica* survey of the northern Gulf of St. Lawrence. Circles show the stratified mean catch rate. Error bars represent upper and lower 95% confidence limits (from Kulka *et al.* 2006).53

Figure 21b. Mean number per tow for Smooth Skate from the Laurentian-Scotian DU, northern Gulf of St. Lawrence Region, *Lady Hammond* survey (see Table 3 for area surveyed). Error bars represent upper and lower 95% confidence limits. 54

Figure 21c. Mean number per tow for Smooth Skate juveniles and adults from the Laurentian-Scotian DU, northern Gulf of St. Lawrence Region. Error bars represent upper and lower 95% confidence limits. Ln transformed data are plotted to the right. 55

Figure 22a. Relative abundance (per 1,000 tows) of Smooth Skate of all sizes from the Laurentian-Scotian DU, southern Gulf of St. Lawrence Region. The line is the three-year moving average. The horizontal dotted line is the long-term mean. 56

Figure 22b. Relative abundance of Smooth Skate juveniles < 48 cm and adults >= 48 cm from the Laurentian-Scotian DU, southern Gulf of St. Lawrence Region. Error bars represent upper and lower 95% confidence limits. The horizontal dotted line is the long-term mean. 57

Figure 23a. Relative abundance of Smooth Skate adults and juveniles combined from the Laurentian-Scotian DU, Scotian Shelf (Div. 4VWX). The horizontal dotted line is the long-term mean. 58

Figure 23b. Mean number per tow of Smooth Skate juveniles and adults from the Laurentian-Scotian DU, Scotian Shelf (Div. 4VWX). Error bars are + 2 SD.59

Figure 24. Number per tow of Smooth Skate from the Georges Bank, Canadian sector. Error bars represent upper and lower 95% confidence limits. 60
Figure 25. Abundance and biomass of Smooth Skate from the Gulf of Maine (USA) spring and fall surveys, 1963-2008. 61
Figure 26. Abundance of fish < 15 cm, year class 0 (McPhie and Campana 2009b), an index of recruitment for the Laurentian-Scotian DU. 62
Figure 27. Estimates of bycatch removals of Smooth Skate in commercial fisheries from the Grand Banks to the Labrador Shelf. In the upper panel data were calculated for each of the DUs that occur in the NL Region jurisdiction (encompassing the Hopedale Channel, Funk Island Deep, and Grand Banks part of the Laurentian-Scotian DU). The middle panel shows these data summed, and the bottom panel shows relative fishing mortality, expressed as removals/survey biomass. 65
Figure 28. Change in abundance of Smooth Skate in relation to various levels of intensity of trawl effort in the Funk Island Deep DU. High refers to places where >25% of the bottom was covered by trawling, low is where 0.01-25% was trawled. Untrawled is where no trawl effort occurred in that year. Refer to Kulka and Pitcher (2001) for details. 66
Figure 29. Landings and discards of Smooth Skate in the southern Gulf of St. Lawrence based on observer data adjusted to total landings. 67
Figure 30. Estimated removals, t, of Smooth Skate from selected directed fisheries in Div. 4X and Divs. 4VsW as derived from observer reports. Observer coverage in other fisheries was insufficient to estimate removals or insignificant numbers of Smooth Skates were reported as bycatch. 68
Figure 31. Relative F (relative fishing mortality) derived from the estimated removals of Smooth Skate and summer RV biomass for each NAFO subdivision.. 69

List of Tables

Table 1a. Global distribution summary for Smooth Skate (after Kulka *et al.* 2006). DUs are bold highlighted. Area is estimated using the SPANS GIS with potential mapping and encompasses anywhere that Smooth Skate were found. Note that the Flemish Cap and part of the Nose of the Grand Bank and Gulf of Maine fall outside Canadian waters. 15
Table 1b. Latitudes and longitudes delineating designatable units. 16
Table 2a. Survey information available from DFO-Newfoundland and Labrador Region research trawl surveys. Various gears have been employed (Yankee-41.5 otter trawl, depicted in brown; Engel-145 otter trawl, blue area; Campelen-1800 shrimp trawl, yellow area) on various vessels. These areas completely encompass the Hopedale Channel, Funk Island Deep and Flemish Cap DUs and a portion of the Laurentian-Scotian DU (Figure 11b). 40
Table 3. Trawl survey information available from DFO Quebec Region in northern Gulf of St. Lawrence (Laurentian-Scotian DU). 41
Table 4. Survey information available from DFO Gulf Region in southern Gulf of St. Lawrence (Laurentian-Scotian DU). 42

Table 5. Summary of main demersal survey data sources for each region. Each line corresponds to a different survey. Refer to Tables 3 and 4 for descriptions of gears used. 42
Table 6. Length and age at 50% maturity for Smooth Skate. 42
Table 7. Growth parameters of Smooth Skate. L_0 is size at hatch (total length, cm), L_{max} is largest observed size, L_{inf} is theoretical largest size from the growth model (either von Bertalanffy or Gompertz), k is the growth coefficient, and A_{max} is the oldest observed fish. 43
Table 8. Estimates of recent minimum trawlable abundance derived from Fisheries and Oceans Canada demersal trawl surveys. Reported abundances are the mean of the last three years that a particular survey was conducted. Survey gear is specified below the area. Abundance in the Nose of the Grand Bank DU is unknown but very low. 44
Table 9. Estimated changes in Smooth Skate populations by proposed DU and region in Canadian waters. Annual rates of change and absolute change are shown over the time period surveyed. Data are not available to calculate decline rates for the Hopedale Channel DU. Gen. = # of generations based on generation time of 16 years. 50

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

The Smooth Skate (*Malacoraja senta* Garman 1885) belongs to the Family Rajidae, within the Class Chondrichthyes, which encompasses all shark and skate species. This species used to be included in the genus *Raja*, but was moved to *Malacoraja* by McEachran and Dunn (1998). This genus, collectively known as soft skates due to a paucity of spines on the wings, contains four species, which are restricted to the Atlantic Basin.

Morphological Description

All species of *Malacoraja* are relatively small and Smooth Skate is one of the smallest in the northwest Atlantic Ocean, with a maximum total length of 66 cm, and weight of 1.2 kg (McEachran 2002, Figure 1). It is distinguished from its congeners by spines that are larger toward the front of the tail but disappear with age on the posterior extent of the tail, by few scapular spines, by a group of 3-15 small orbital spines in front of and around each eye (McEachran 1973; McEachran 2002; McEachran and Dunn 1998), and by thin, translucent cartilage on its snout. Smooth Skate has one of the longest tails relative to total length, equal in length to the disk, making it easy to distinguish from other northwest Atlantic skates. Juveniles can be distinguished from other northwest Atlantic skates by 1-4 irregular pale crossbars or half-bars on the tail, each outlined by a dark band (Figure 1). These fade after the fish are 1 year old.

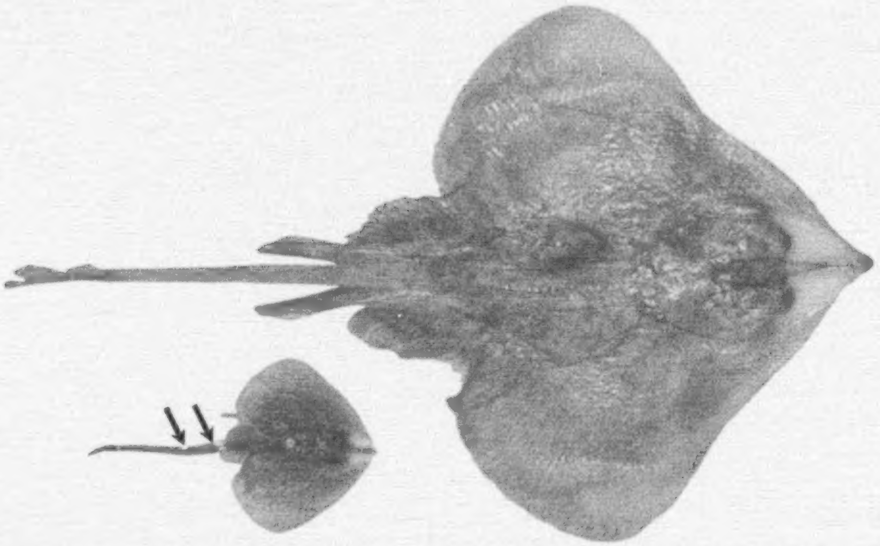


Figure 1a. Male Smooth Skate taken from the Funk Island Deep. Inset – recently hatched 12 cm specimen. Note white markings on the tail indicated by the arrows.

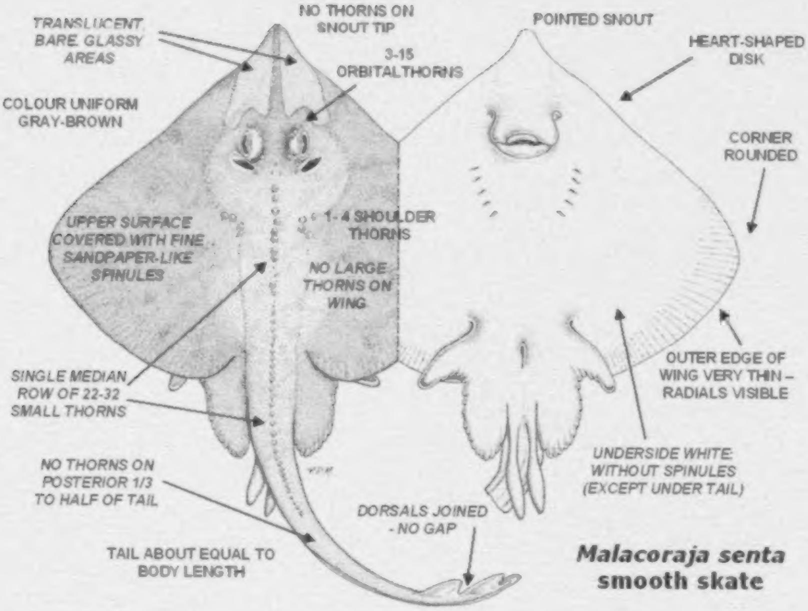

TRANSLUCENT BARE GLASSY AREAS
NO THORNS ON SNOUT TIP
3-15 ORBITALTHORNS
POINTED SNOUT
HEART-SHAPED DISK
COLOUR UNIFORM GRAY-BROWN
CORNER ROUNDED
UPPER SURFACE COVERED WITH FINE SANDPAPER-LIKE SPINULES
1-4 SHOULDER THORNS
NO LARGE THORNS ON WING
SINGLE MEDIAN ROW OF 22-32 SMALL THORNS
OUTER EDGE OF WING VERY THIN – RADIALS VISIBLE
NO THORNS ON POSTERIOR 1/3 TO HALF OF TAIL
UNDERSIDE WHITE: WITHOUT SPINULES (EXCEPT UNDER TAIL)
DORSALS JOINED - NO GAP
TAIL ABOUT EQUAL TO BODY LENGTH
Malacoraja senta
smooth skate

Figure 1b. Drawing of Smooth Skate highlighting morphometric attributes used to differentiate it from other species (after Sulak *et al.* 2009).

Population Spatial Structure and Variability

Smooth Skate form five disjunct concentrations (Figure 2): in the Hopedale Channel (NAFO Div. 2H); Northeast Newfoundland Shelf/Funk Island Deep (Div. 2J3K and northern 3L); Nose of the Grand Bank; Flemish Cap (Div. 3M), and Laurentian Channel/Southwest Grand Banks/Scotian Shelf (Div. 3NOP4RSTVWX5Z). These localities are separated by wide areas where the species has never been found despite great sampling effort. A detailed description is in the Distribution section. The fish on the Flemish Cap and in the Gulf of Maine are outside Canadian territorial waters. Because it is a relatively sedentary species at all life stages, it appears that there is little possibility of mixing among the widely separated concentrations and thus genetic isolation is highly likely, as discussed in the section on Dispersal and Migration.

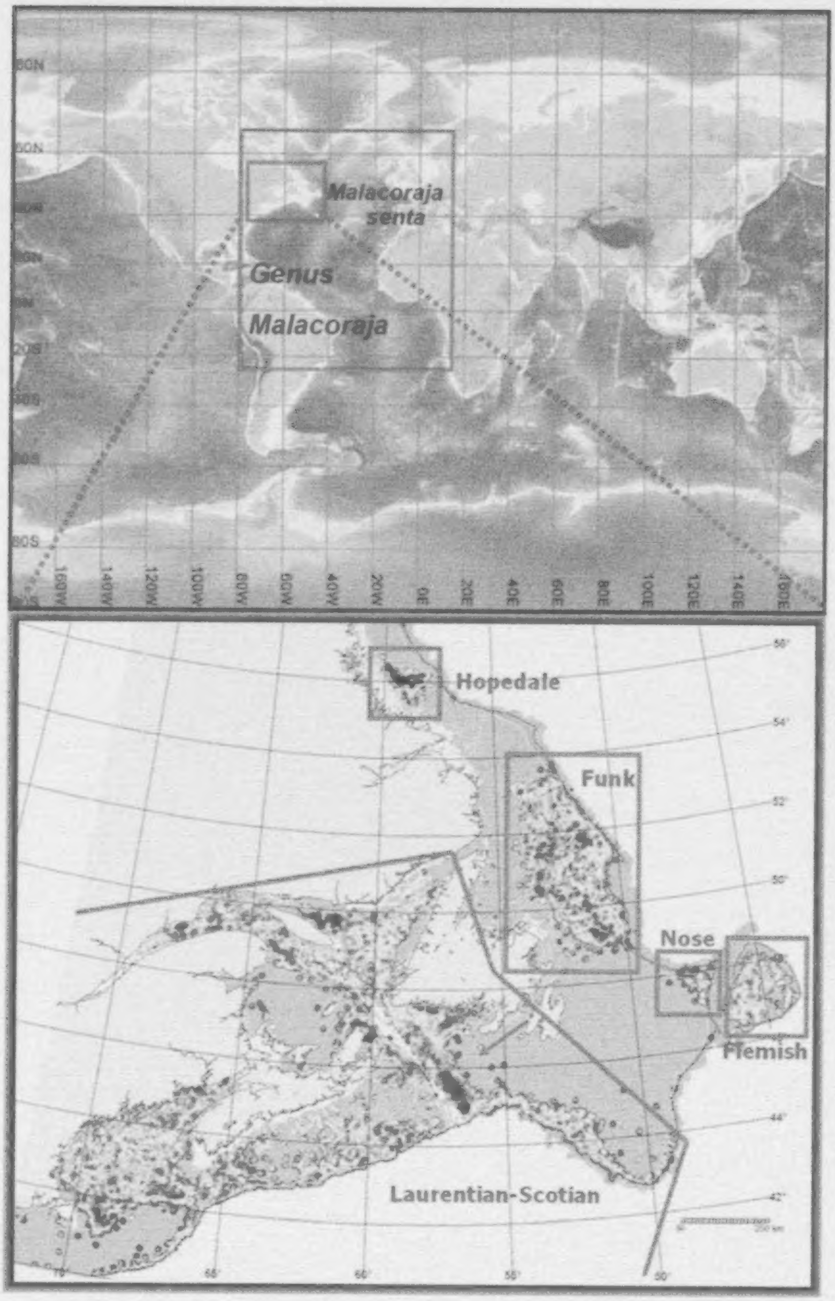

Malacoraja
senta
Genus
Malacoraja
80N
60N
20S
80S
160W
140W
120W
100W
80W
60W
40W
20W
0E
20E
40E
60E
80E
100E
120E
140E
160E
Hopedale
Funk
Nose
Flemish
Laurentian-Scotian
56°
54°
52°
50°
44°
42°
70°
65°
60°
55°
50°
200 km

Figure 2a. Upper - global distribution of the genus *Malacoraja* and Smooth Skate, *M. senta*. Within the red squares, the species is restricted to portions of the continental shelf. Lower - Distribution of Smooth Skate catches in Canadian and US trawl surveys. Colour surface denotes density level of captures. Red lines and labels delineate the proposed DUs. See Figure 2c for the 200-mile limit and the Canada/USA border.

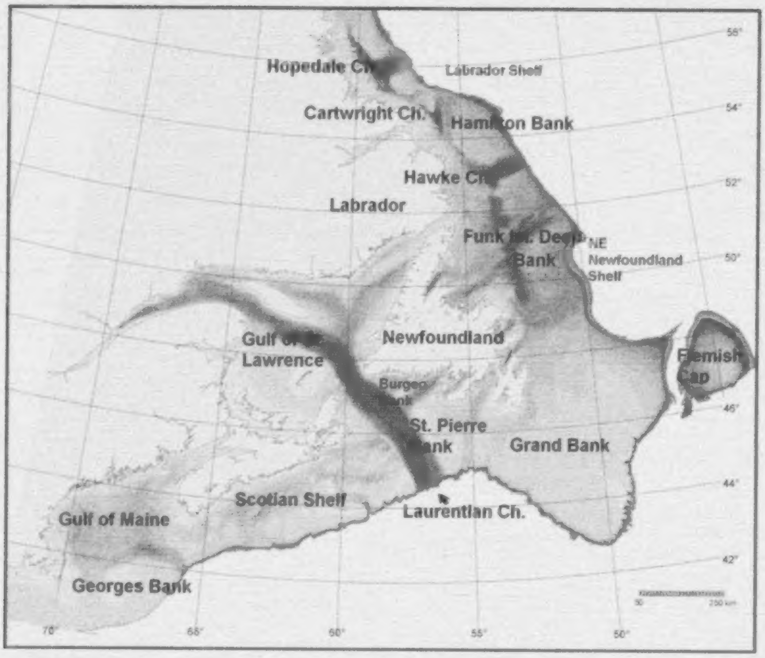

Hopedale Ch.
Labrador Shelf
Cartwright Ch.
Hamilton Bank
Hawke Ch.
Labrador
Funk Isl. Deep
Bank
NE
Newfoundland
Shelf
Gulf of St.
Lawrence
Newfoundland
Flemish
Cap
Burgeo
Bank
St. Pierre
Bank
Grand Bank
Scotian Shelf
Laurentian Ch.
Gulf of Maine
Georges Bank
56°
54°
52°
50°
46°
44°
42°
70°
65°
60°
55°
50°

Figure 2b. Bathymetry and geographic areas referred to in this document. Blue areas comprise the continental shelf and upper slope out to a bottom depth of 1000 m.

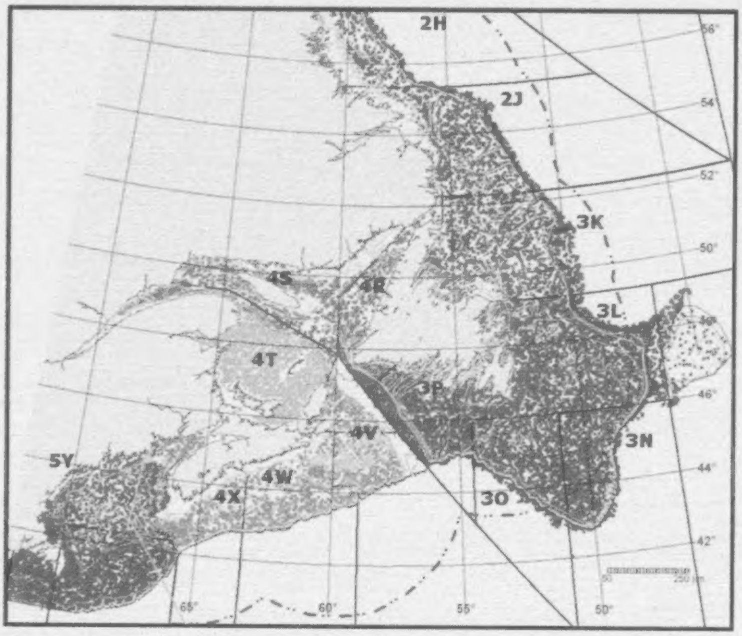

2H
2J
3K
4S
4R
3L
4T
3P
3N
4V
5Y
4W
4X
3O
56°
54°
52°
50°
46°
44°
42°
65°
60°
55°
50°

Figure 2c. Distribution of sampling effort from Canadian and US trawl surveys from 1970-2009. Coloured dots show the DFO Regional and USA survey sets: green-NL. blue-Quebec, teal-Gulf, red-Maritimes, purple-USA.

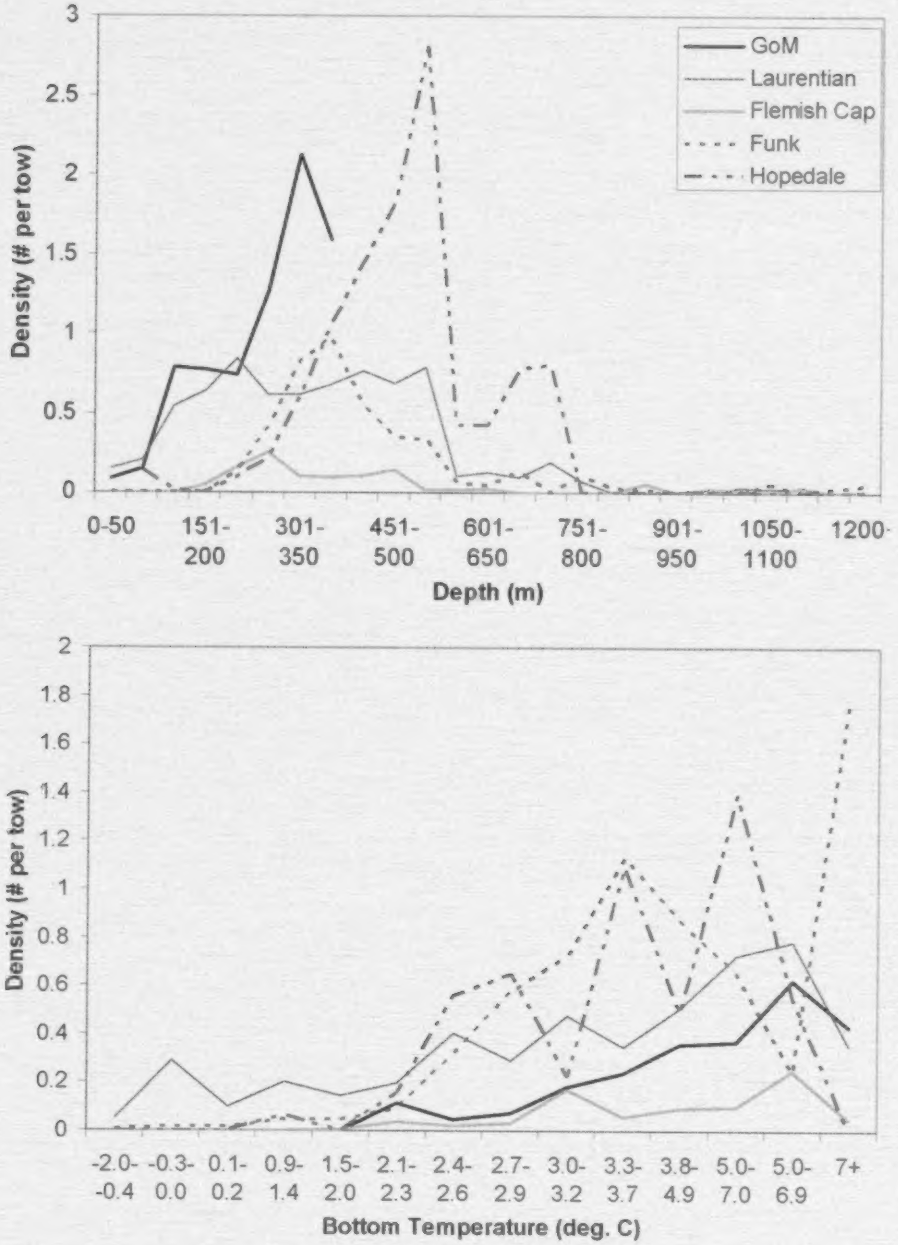


Figure 3. Distribution of Smooth Skate for the various DUs over their range with respect to temperature and depth during 1971-2005 (after Kulka *et al.* 2006). GoM refers to the Gulf of Maine in the Laurentian-Scotian DU.

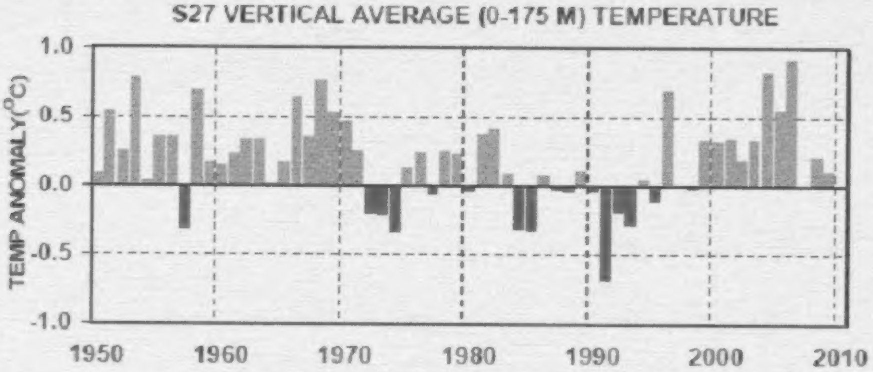


Figure 4. Long-term water temperature observations for the Grand Banks, Station "27" near the Avalon Peninsula, Newfoundland.

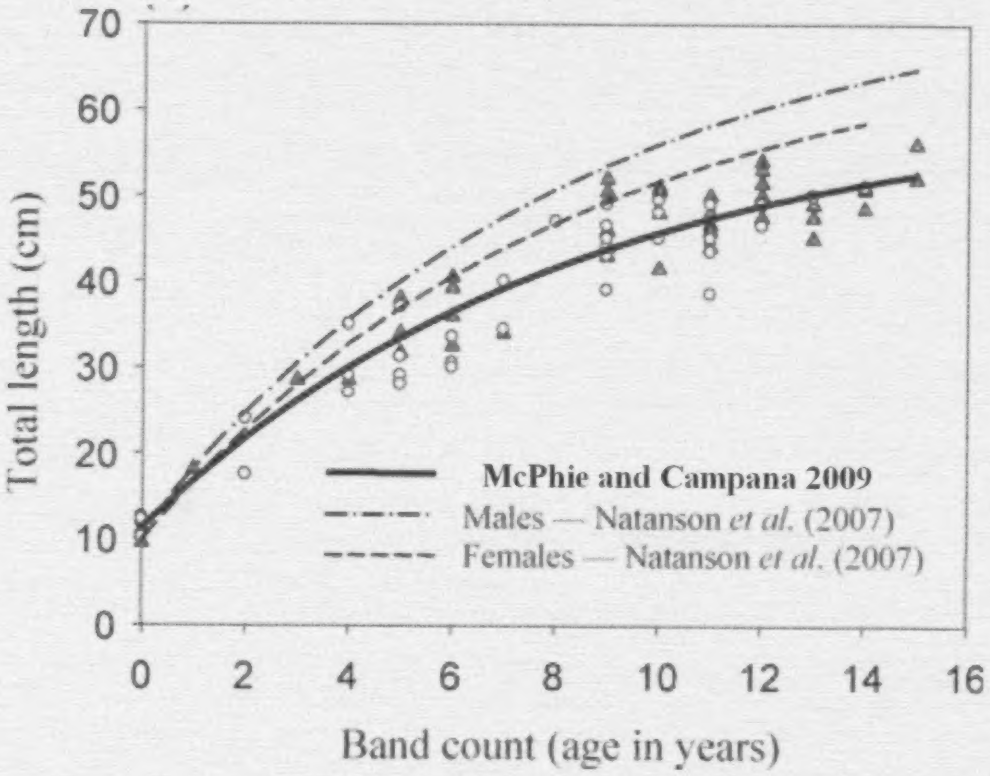


Figure 5. Growth curves for Smooth Skates. Scatterplot of total length at age for males (grey triangle) and females (white circle) are fitted with a traditional three-parameter von Bertalanffy growth curve. Growth models from previously published studies from other geographic regions are overlaid (after McPhie and Campana 2009).

Designatable Units

Based on temporally consistent geographic disjunctions described under Distribution, as well as limited dispersal characteristics described under Dispersal and Migration, the concentrations described above are proposed as four designatable units (DUs). These will be referred to as Hopedale Channel, Funk Island Deep, Nose of the Grand Bank, and Laurentian-Scotian. Two of the DUs, Hopedale Channel and Funk Island Deep, fall exclusively in Canadian waters, whereas 77% of the Nose of the Grand Bank DU occurs in international waters. The Laurentian-Scotian DU extends slightly (< 0.5%) into international waters on the southeastern Grand Banks and the southwestern edge is contiguous with Georges Bank concentration in USA waters.

The proposed DUs meet the COSEWIC criteria of "distinctness" and "significance". They are "distinct" because they are geographically disjunct, with little or no possibility of genetic exchange among them, based on knowledge of dispersal and movement of individuals. Thus there is little likelihood of any DU being repopulated from another. Such patterns of clear disjunction are extremely rare among temperate marine species. This is relevant to the "significance" criterion because loss of some of these proposed DUs would result in a significant gap in the range of the species in Canada. Furthermore, any compromise to the geographic mosaic of the species would be a significant loss, given the unusual nature of this distribution for temperate marine fishes.

Within the proposed Laurentian-Scotian DU there are minor disjunctions (<100 km) and different trends in abundance and area occupied (discussed under Distribution). Within this DU it is uncertain how the Scotian Shelf fish are related to fish in the Gulf of St. Lawrence and Grand Banks to the north and to those in the Gulf of Maine to the south. Population structure in this area is further complicated by increased fragmentation as abundance has declined. These observations suggest the possibility of some degree of isolation and therefore the possibility of a more complex population structure than a single breeding unit within this area.

Special Significance of the Species

Smooth Skate is endemic to the northwest Atlantic and much of its distribution is in Canada. It has a very unusual biogeography for a temperate marine fish, showing a disjunct distribution within its Canadian range.

DISTRIBUTION

Global Range

The genus *Malacoraja* occurs only in the Atlantic Ocean basin (Figure 2a, upper panel). Of the 4 species in this genus, Smooth Skate is the only one endemic to the shelf off North America. It is found from the southern Georges Bank north to the Labrador Shelf (Figure 2a and b; Templeman 1965; McEachran 1973; McEachran and

Musick 1975; Clay 1991; Simon and Comeau 1994; Kulka *et al.* 1996; Packer *et al.* 2003; Kulka *et al.* 2006; Swain *et al.* 2006; NOAA/NMFS 2009). Between Lat. 39° and 60°, the full latitudinal range of the species, 9% of all surveys sets contained Smooth Skate (Kulka *et al.* 2006), making it the second or third most commonly encountered skate species, after thorny skate (*Amblyraja radiate*) and/or winter skate (*Leucoraja ocellata*).

Although the northernmost record for Smooth Skate is at Lat. 60°, records beyond Lat. 56.5° are very rare (0.08% of survey sets north of this latitude contain them). Similarly, occurrences south of Lat. 40° are rare (found in < 0.35% of survey sets).

Canadian Range

Approximately 80% of the global population of Smooth Skate occurs in Canadian waters (Figure 2a, Table 1). It is distributed primarily in the troughs separating shallower banks, from the Hopedale Channel on the Labrador Shelf to the Gulf of Maine and outer Georges Bank, contiguous with fish in USA territorial waters (Darbyson and Benoît 2003; Kulka *et al.* 2006).

Table 1a. Global distribution summary for Smooth Skate (after Kulka *et al.* 2006). DUs are bold highlighted. Area is estimated using the SPANS GIS with potential mapping and encompasses anywhere that Smooth Skate were found. Note that the Flemish Cap and part of the Nose of the Grand Bank and Gulf of Maine fall outside Canadian waters.

Designatable Unit/Area	**Area (km^2 /000s)**	**Percent of Area**
Hopedale Channel	11.6	2.0
Funk Island Deep (Northeast Newfoundland Shelf)	106.4	18.2
Nose of the Grand Banks	11.0	1.9
Flemish (Cap, international)	29.6	5.1
Laurentian-Scotian (Ch/surrounds)	283.0	48.4
Gulf of Maine (USA)	142.8	24.4
Total area occupied and percent of shelf area occupied	584.4	46.85
Total shelf area (0-800 m, Lat 40 to 56.5°)	1247.5	
Range Limits		
Latitudinal range	Lat. 40 to 56.5°	
Northerly/Southerly records	Lat. 30 to Lat. 60°	
	Highest Densities	**Extreme records**
Depth (highest densities over entire range)	150-550 m	25-1436 m
Bottom temperature (highest densities over entire range)	2.7-10°	-1.3-15.7

Table 1b. Latitudes and longitudes delineating designatable units.

Designatable Unit	North Latitude	South Latitude	NAFO Div
Hopedale Channel	57.7°	55.2°	2H
Funk Island Deep	54.0°	48.5°	2JK (part of 3L)
Nose of the Grand Bank	48.5°	47.0°	part of 3L
Laurentian-Scotian	51.5°	Can.-USA border	3NOPRST4VWX5Y

Search Effort

Fisheries and Oceans (DFO) demersal research trawl surveys form the basis for determining where Smooth Skate occur. A detailed description of these surveys can be found in Kulka (2006), in the COSEWIC report on Thorny Skate, and below under Population Sizes and Trends.

Distribution Mapping and Area of Occupancy

Distribution mapping was done differently among DFO regions but all used research trawl survey data. For NL (as well as the overall range maps), SPANS GIS (Anon. 2003) was used. Details are described in Kulka (1998) and Kulka *et al.* (2006). DFO survey trawl gear changes resulted in the scale of maps representing a different catch rate (density) after fall 1995. Survey data were grouped into four periods corresponding to periods of differing population status for the DU's (Kulka *et al.* 2006). For the Gulf Region (southern Gulf of St. Lawrence), geographic distribution was mapped using ACON (http://www.mar.dfo-mpo.gc.ca/science/acon). Shaded contours were drawn using Delaunay triangles. For the Quebec (northern Gulf) and Maritimes regions, expanding symbols based on data summarized to 10 minute squares (or as otherwise specified on the map) was used.

Unless otherwise stated, AO values are design-weighted area of occupancy (DWAO), which incorporates the stratified random survey design (Swain and Sinclair 1994; Smedbol *et al.* 2002). AO (A_t) was calculated for each size class of skates in year t as follows:

$$A_t = \sum_{k=1}^{S} \sum_{j=1}^{N_k} \sum_{i=1}^{n_j} \frac{a_k}{N_k n_j} I \quad \text{where } I = \begin{cases} 1 \text{ if } Y_{ijkl} > 0 \\ 0 \text{ otherwise} \end{cases}$$

where a_k is the area of the stratum k, Y_{ijkl} is the number of fish in size class l caught in tow i at site j in stratum k, N_k is the number of sites sampled in stratum k, n_j is the number of tows conducted at site j, and S is the number of strata. In order to describe changes in geographic concentration, the minimum area containing 95% of skates, following Swain and Sinclair (1994), was calculated for the Gulf Region as well as the DWAO. Change in AO was calculated as the ratio of the mean AO of first 5 years of data available to mean AO of last 5 years or some portions when the AO was stable during the early and latter period.

There were changes in fishing gear that affected catchability of Smooth Skate. Corrections do not exist for probability of capture. However, it is unlikely that estimates of area of occupancy are greatly affected by gear changes unless there are areas where fish were captured with one type of gear but not with another. This was not observed. In the Newfoundland surveys there were changes in areas and depths surveyed over the years, with the addition of surveys at 900-1500 m. However, effects on estimates of AO were likely to have been minor, since approximately 90% of the skates are taken in surveys between 70 and 480m (see below).

The area encompassing all regions where Smooth Skate were captured in trawl surveys since 1947 covers 547,000 km^2 or 47% of the shelf area within its range (Table 1). Area occupied in any given year is lower, as described below.

Hopedale Channel DU (NL Region)

The Hopedale Channel DU comprises 2% of the global area occupied by Smooth Skate (Table 1, from Kulka *et al.* 2006, Figure 2a, 4). Insufficient data were available to calculate changes in AO; the area was surveyed in only 14 years since 1977 and not always completely. The extent of the distribution of Smooth Skate appears to have fluctuated, including an increase since 1990 (Figure 6b).

Funk Island Deep DU (NL Region)

This DU comprises 18.2% of the long-term global area occupied (Table 1) and covers the Funk Island Deep and surrounding troughs (Figure 6). Over the life of the trawl surveys (1947 to present), no Smooth Skates were caught between the southern end of the Hopedale Channel concentration and the northern extent of the Funk Island Deep DU (a distance of 330 km). Extent and density diminished dramatically starting in the early 1980s and fragmentation of the concentration was first observed in the 1990s (Figure 6). By 2000-2004, only a remnant of the original distribution remained. Limited recovery was observed at the northern extent of the concentration after 2005.

Following a steady decline from 1980 to 2000, AO stabilized at 2,000 km^2 from 2000 to 2004, about 4% of the AO in the late 1970s to early 1980s (Figure 7). AO has since increased to 13,500 km^2 or 21% of the peak period.

Flemish Cap

The Flemish Cap falls outside of Canadian waters and is not considered a DU. Thus, AO is not calculated for this area.

Nose of the Grand Bank DU (international waters and NL Region)

The Nose of the Grand Bank DU is a minor part (1.9%) of the global distribution (Figure 2, Table 1) and 77% of this area is in international waters. The average number of fish/year in surveys was 0.7 and the encounter rate (% of sets with Smooth Skate) was 0.6%. In only 11 of 37 years was Smooth Skate encountered there. Data were not available to calculate changes in the AO.

Laurentian-Scotian DU (All DFO Regions)

The Laurentian-Scotian DU is separated from the Funk Island Deep DU by 400 km and encompasses the southwest Grand Banks, the Gulf of St. Lawrence, the Scotian Shelf, the Bay of Fundy, and Georges Bank (Figure 2 and 6). It comprises 48% of the global area of the species, 70% of that area in Canadian waters (Table 1, Kulka *et al.* 2006). On the Scotian Shelf, the distribution is fragmented, but the distance across these disjunctions is only about 20-100 km and variable over time.

The following description of the Laurentian-Scotian DU is presented by DFO region separately because the surveys used to describe distribution constitute regionally distinct data that cannot be combined due to unresolved catchability issues among sampling gears.

Southwest Grand Banks and southern Laurentian Channel) (NL Region surveys)

Concentrations in the Laurentian Channel have become more dense since 2000 than in prior years (Figure 6), consistent with a substantial increase in abundance (see Population Sizes and Trends). AO fluctuated around 20,000 km^2 from the mid-1970s to 1993, increasing to about 30,000 km^2 after 1995 (Figure 8). AO in 2008-2010 was 2.4 times greater than in the first three years of the survey (1975-1977).

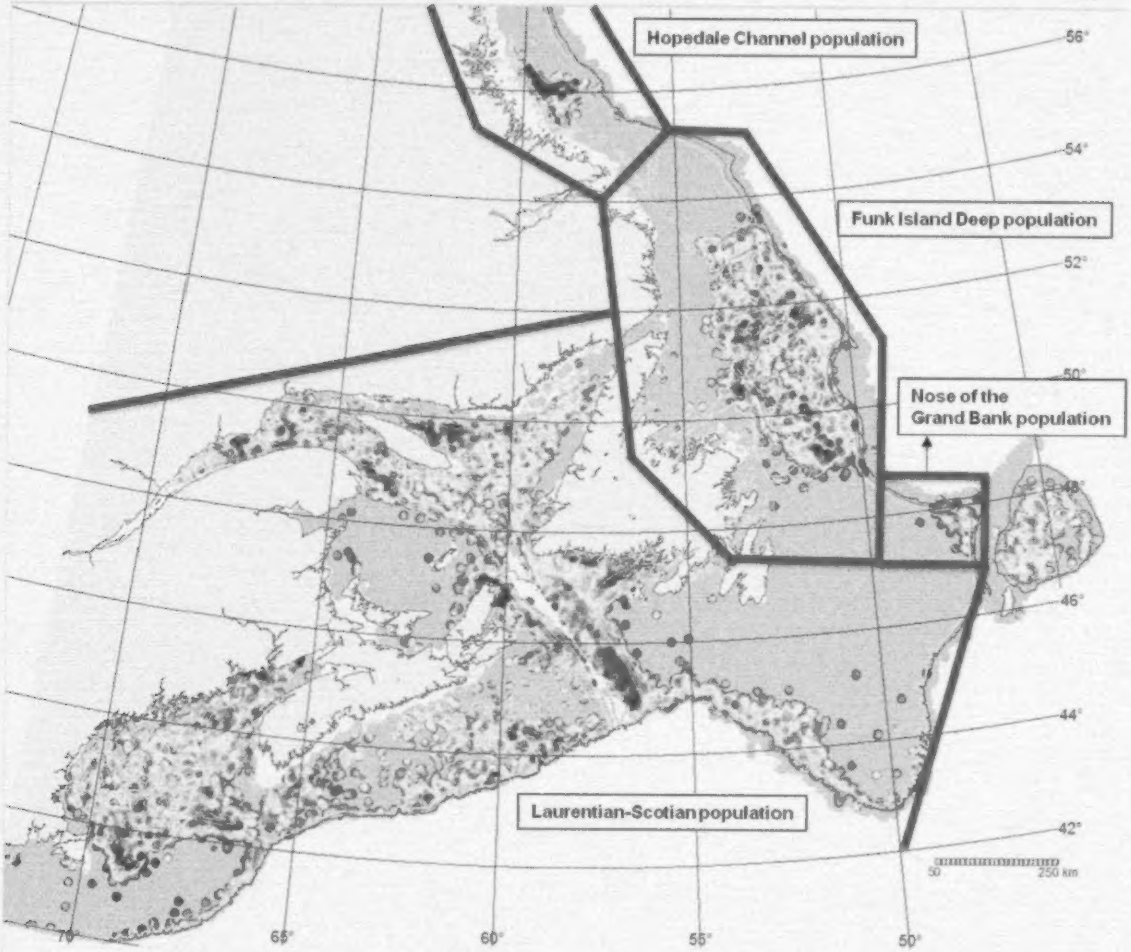

Hopedale Channel population
Funk Island Deep population
Nose of the
Grand Bank population
Laurentian-Scotian population
56°
54°
52°
50°
48°
46°
44°
42°
70°
65°
60°
55°
50°
50
250 km

Figure 6a. Distribution of Smooth Skate in the waters off Newfoundland and Labrador (cumulative area from 1971-2009). Grey areas denote areas sampled but with no catches, green are low catches grading to red with high catches expressed in mean number per tow. The Flemish Cap is not fully illustrated as nearly all of that area occurs outside the 200-mile limit of Canada.

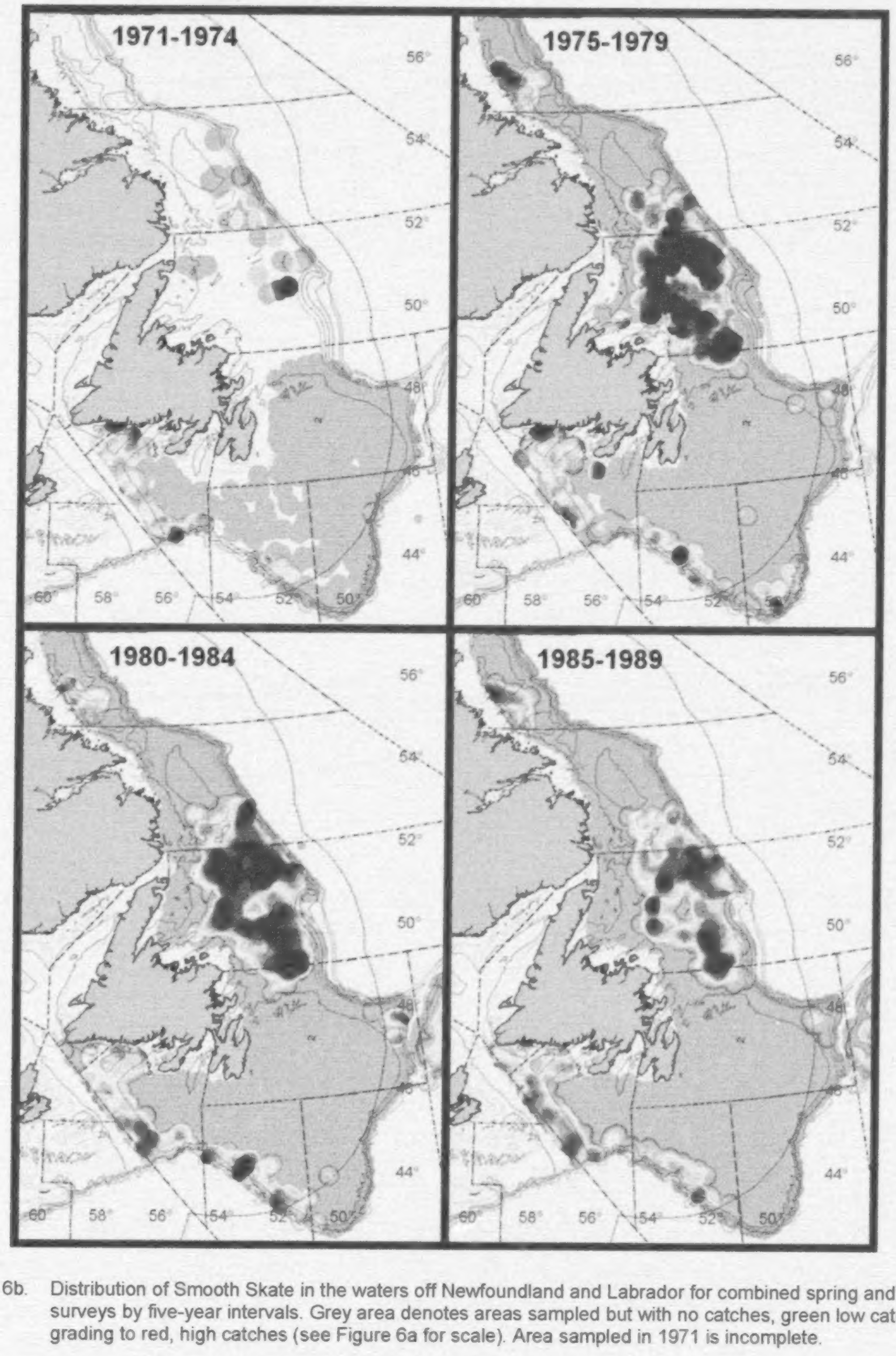

1971-1974
1975-1979
1980-1984
1985-1989
56°
54°
52°
50°
48°
46°
44°
60°
58°
56°
54°
52°
50°

Figure 6b. Distribution of Smooth Skate in the waters off Newfoundland and Labrador for combined spring and fall surveys by five-year intervals. Grey area denotes areas sampled but with no catches, green low catches grading to red, high catches (see Figure 6a for scale). Area sampled in 1971 is incomplete.

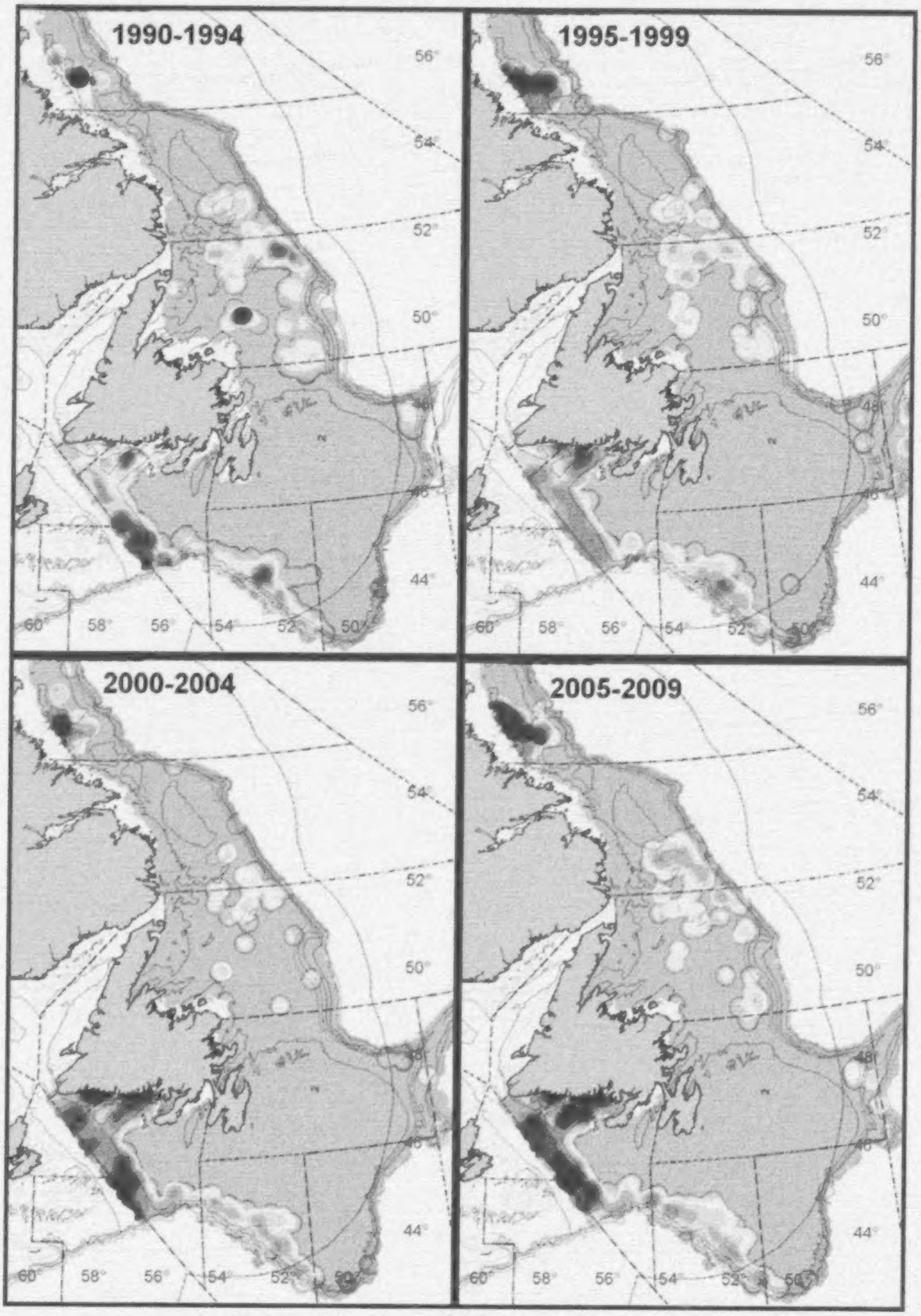

1990-1994
1995-1999
2000-2004
2005-2009
56°
54°
52°
50°
48°
46°
44°
60°
58°
56°
54°
52°
50°

Figure 6b cont. Distribution of Smooth Skate in the waters off Newfoundland and Labrador for combined spring and fall surveys by five-year intervals. Grey areas denote areas sampled but with no catches, green low catches grading to red, high catches (see Figure 6a for scale).

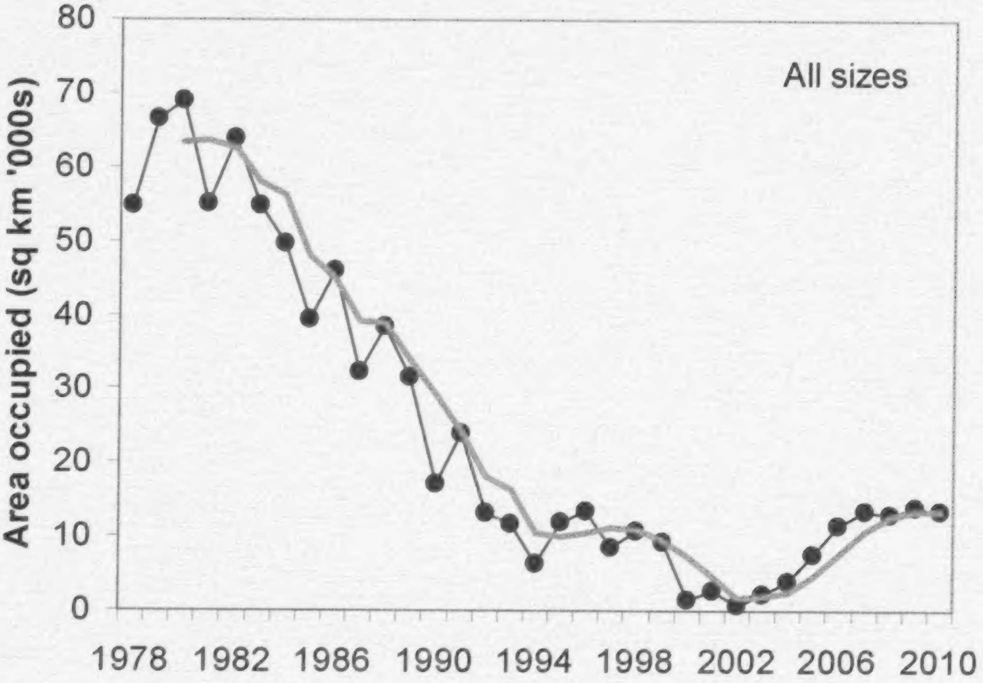


Figure 7. Change in area of occupancy of the Funk Island Deep DU (Div. 2J3K and northern 3L). The red line is the 3-year running average.

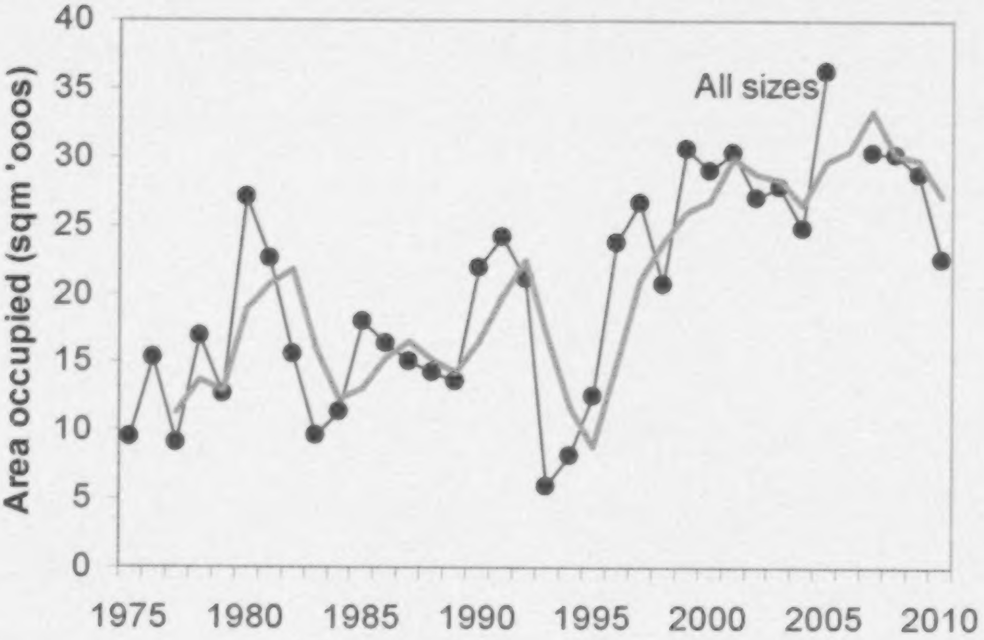


Figure 8. Change in area of occupancy of the Grand Banks portion (Div. 3LNOPs) of the Laurentian-Scotian DU. The red line is the 3-year running average.

Northern Gulf of St. Lawrence (Quebec Region surveys)

Three surveys indicate that Smooth Skate occupy most of the northern Gulf (Figure 9). AO of adult Smooth Skate averaged 20,000 km^2 up to 2001, increasing to about 76,000 km^2 by 2008-2010 (Figure 10), a 3.8 times increase in AO from 1991 to 2010. Juveniles underwent a greater increase than adults.

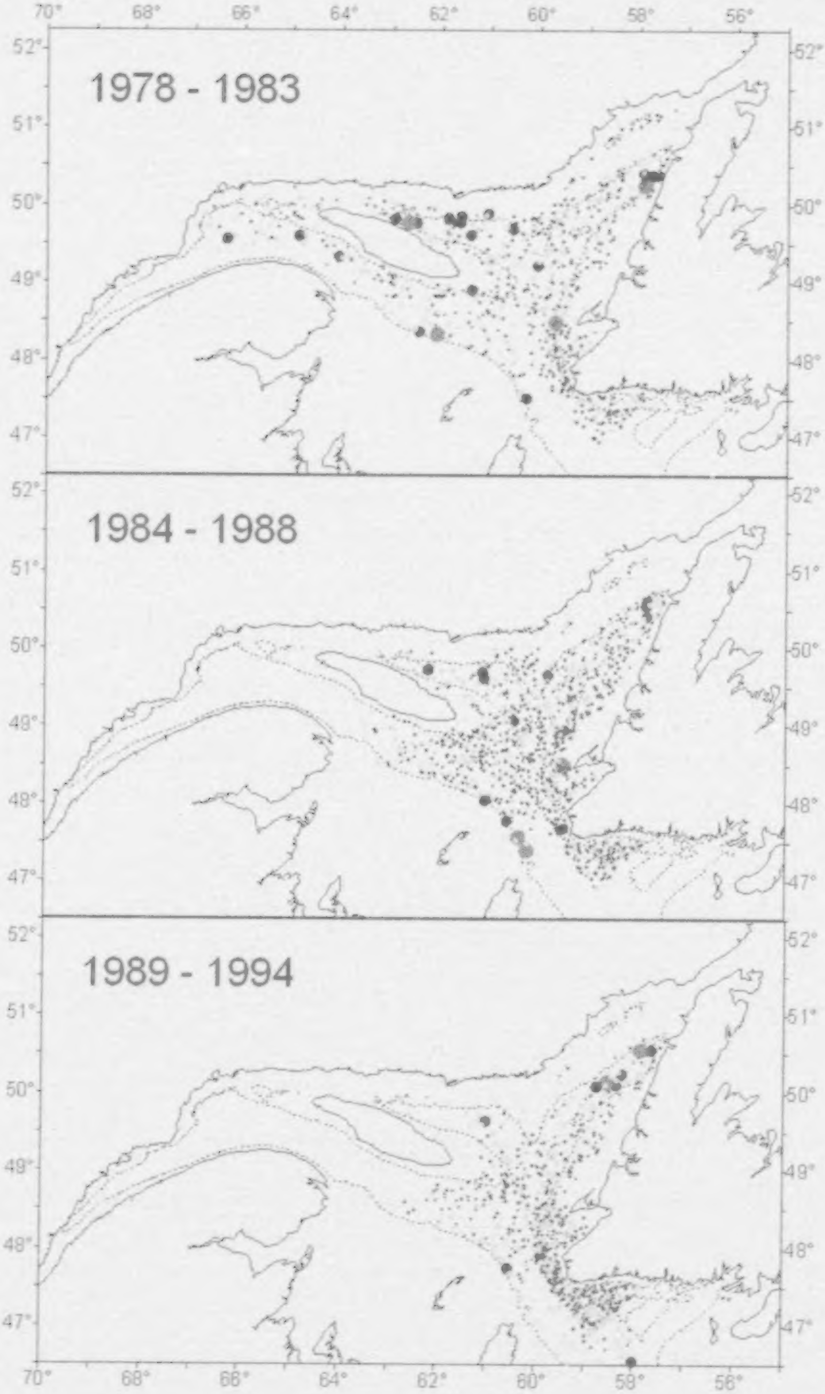

1978 - 1983
1984 - 1988
1989 - 1994
70°
68°
66°
64°
62°
60°
58°
56°
52°
51°
50°
49°
48°
47°

Figure 9a. Distribution of Smooth Skate in the northern Gulf of St. Lawrence part of the Laurentian-Scotian DU, based on *Gadus Atlantica* survey 1978-1994. See Figure 9b for legend with colour codes.

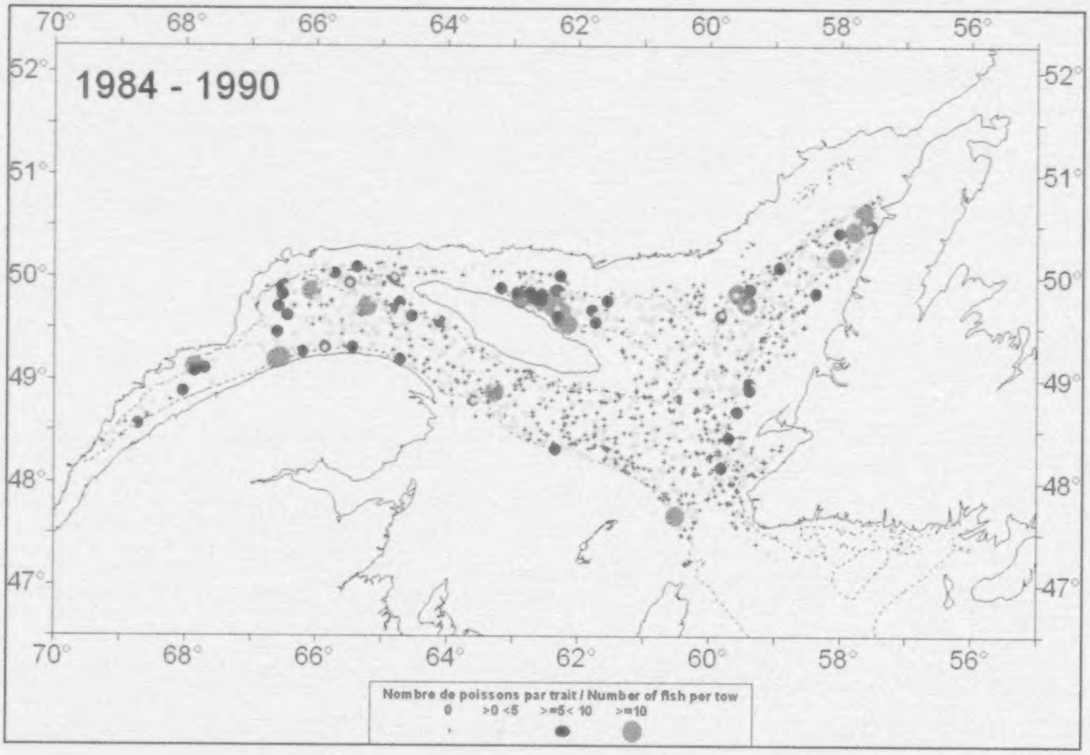
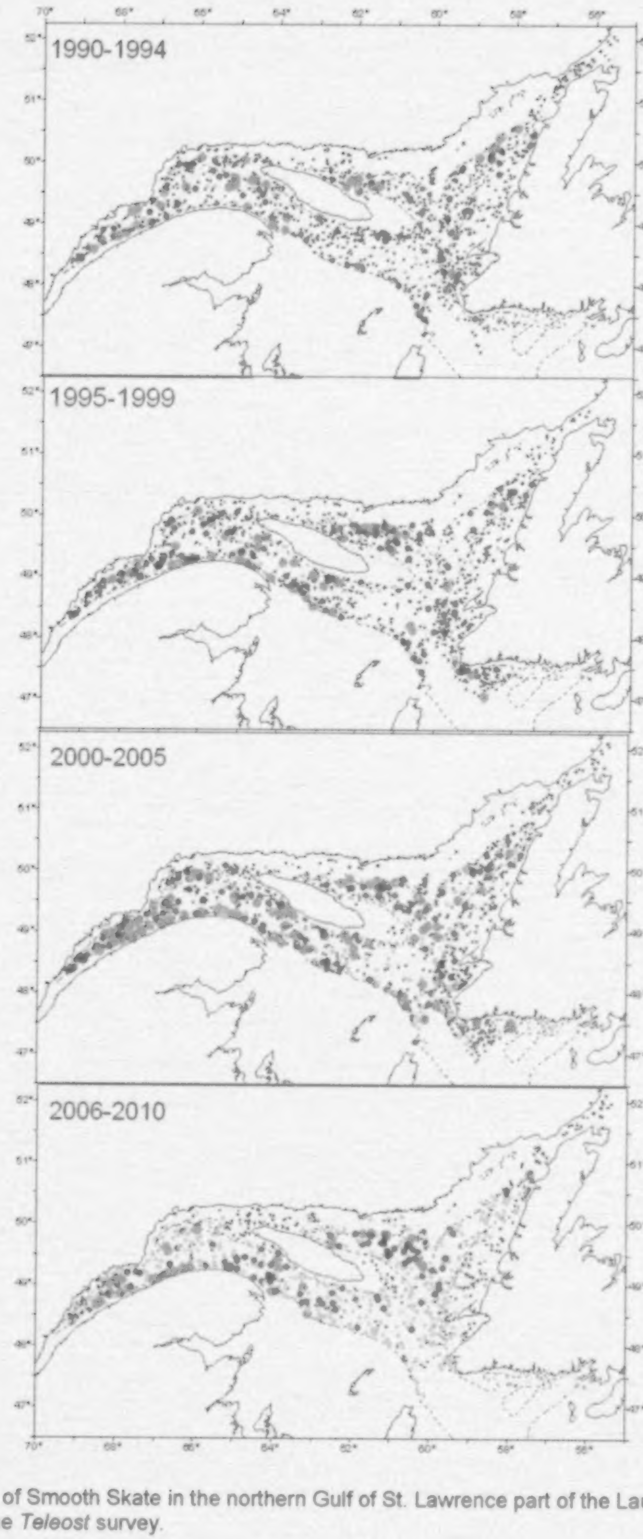

1984 - 1990
70°
68°
66°
64°
62°
60°
58°
56°
52°
51°
50°
49°
48°
47°
Nombre de poissons par trait / Number of fish per tow
0
>0 <5
>=5< 10
>=10

Figure 9b. Distribution of Smooth Skate in the northern Gulf of St. Lawrence part of the Laurentian-Scotian DU, based on the *Lady Hammond* survey.


1990-1994

1995-1999

2000-2005

2006-2010

70°
68°
66°
64°
62°
60°
58°
56°
52°
51°
50°
49°
48°
47°

Figure 9c. Distribution of Smooth Skate in the northern Gulf of St. Lawrence part of the Laurentian-Scotian DU based on the *Teleost* survey.

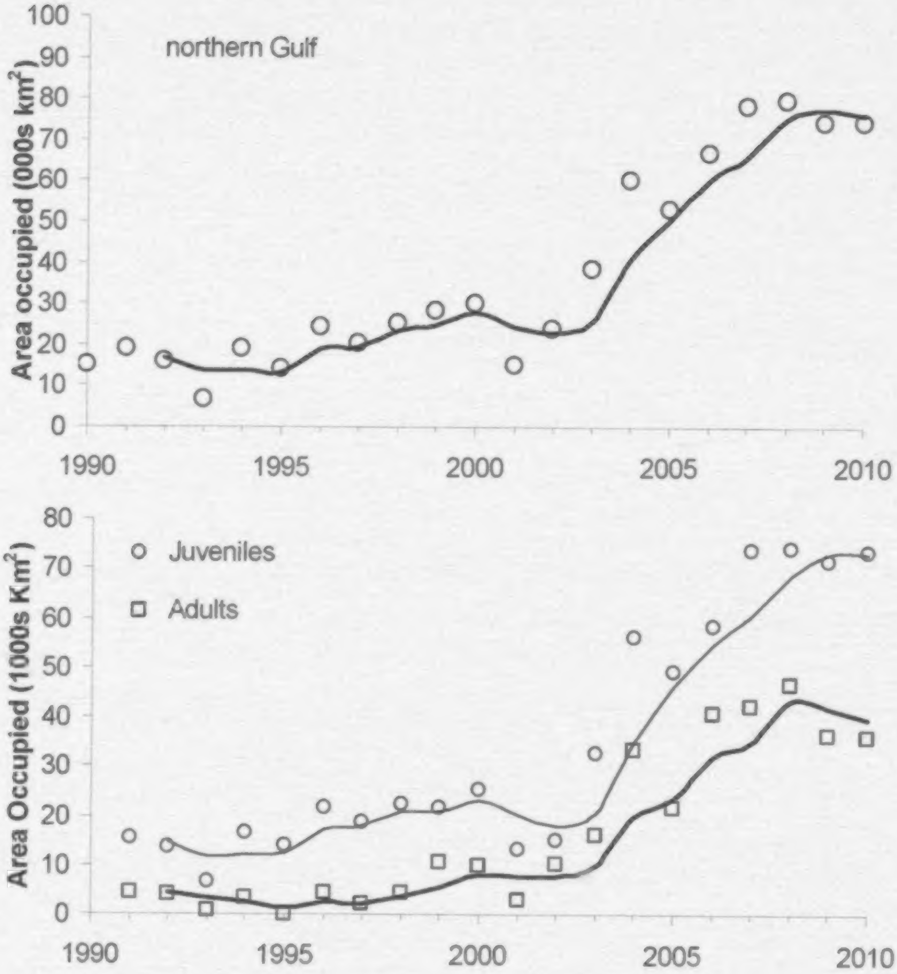


Figure 10. Change in area of occupancy (DWAO) of the northern Gulf of St. Lawrence portion of the Laurentian-Scotian DU based on the *Teleost* survey equivalents. Top panel shows all fish sizes combined and the bottom shows adults and juveniles separately.

Southern Gulf of St. Lawrence (Gulf Region surveys)

Smooth Skate in the southern Gulf are distributed primarily along the slope of the Laurentian Channel (Figure 11a, Swain and Benoît 2012) contiguous with the fish in the northern Gulf. Little geographic segregation is evident between length classes (Figure 11b). Juvenile AO fluctuated over time with no trend since the early 1990s (Figure 12; Swain and Benoît 2012). Adult trends were similar, with AO slightly lower in recent years than at the start of the series.

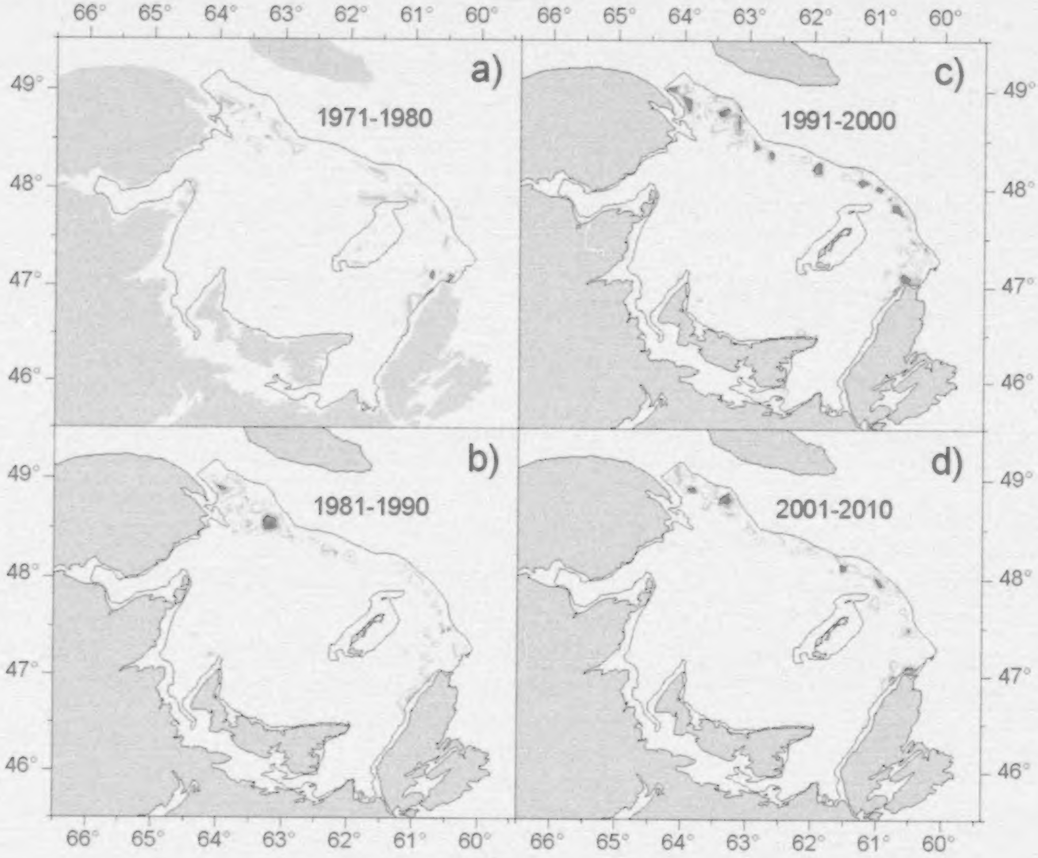

a)
1971-1980
b)
1981-1990
c)
1991-2000
d)
2001-2010
66°
65°
64°
63°
62°
61°
60°
49°
48°
47°
46°

Figure 11a. Distribution of Smooth Skate in the southern Gulf of St. Lawrence part of the Laurentian-Scotian DU.

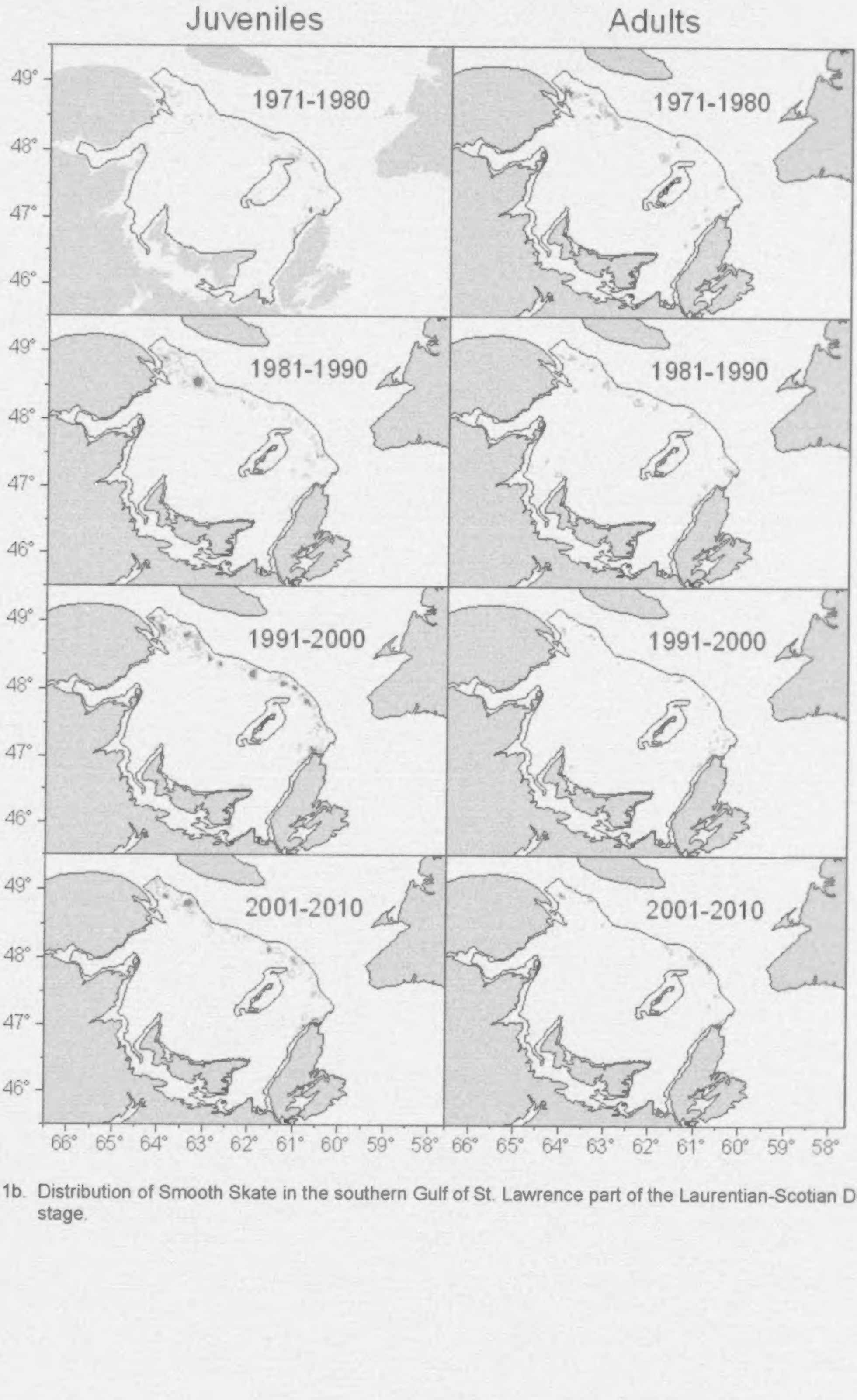

Juveniles
Adults
1971-1980
1971-1980
1981-1990
1981-1990
1991-2000
1991-2000
2001-2010
2001-2010
49°
48°
47°
46°
66°
65°
64°
63°
62°
61°
60°
59°
58°

Figure 11b. Distribution of Smooth Skate in the southern Gulf of St. Lawrence part of the Laurentian-Scotian DU by stage.

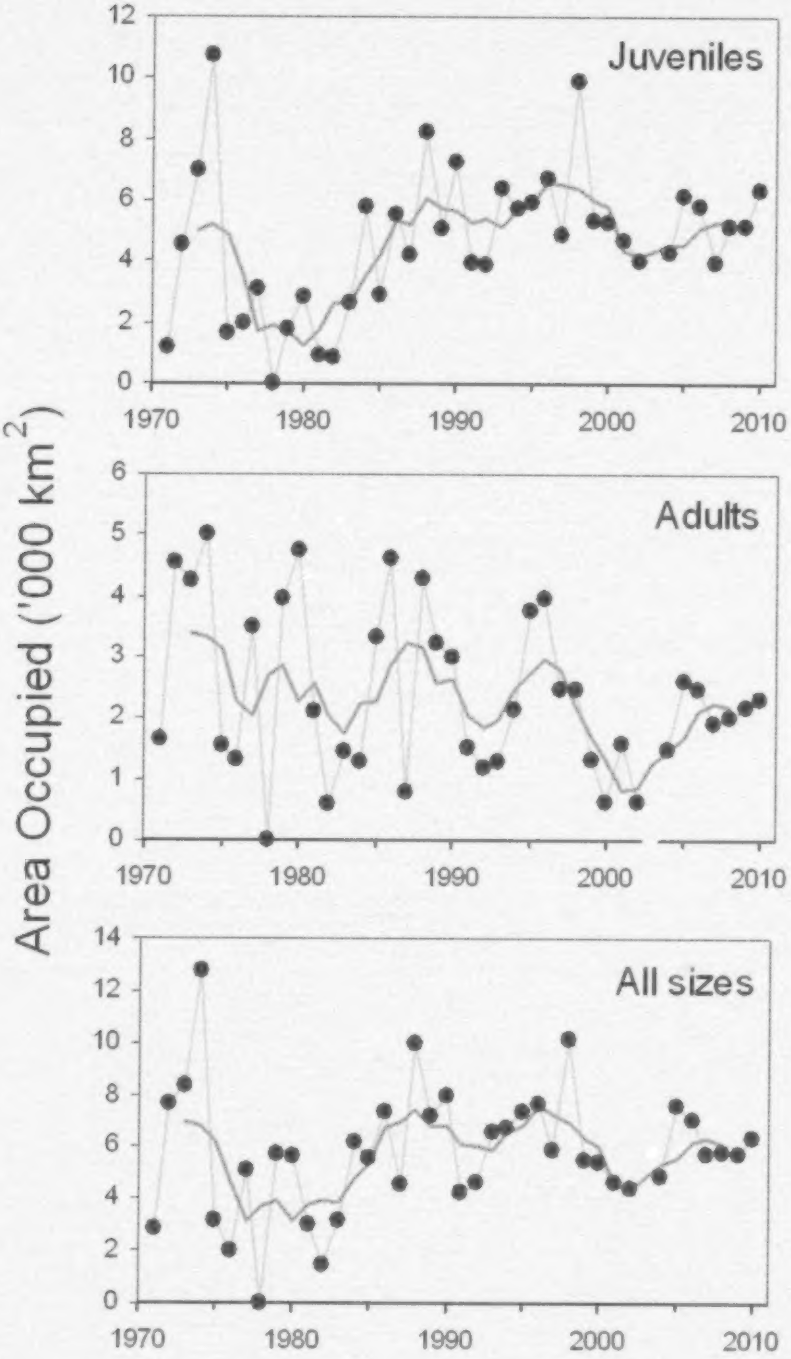


Figure 12. Change in area of occupancy (DWAO) of the southern Gulf of St. Lawrence portion of the Laurentian-Scotian DU. The red line is the 3-year running average.

Scotian Shelf (Maritimes Region surveys)

Two concentrations occur on the eastern shelf: a) contiguous with the fish in the Laurentian Channel, and b) on the Banquereau and Sable Island Banks (see Figure 2b). Since 1970, Smooth Skate distribution on the Banquereau/Sable Island Banks has diminished and fragmented (Figure 13), whereas the extent and density of fish along the edge of the Laurentian Channel has changed little.

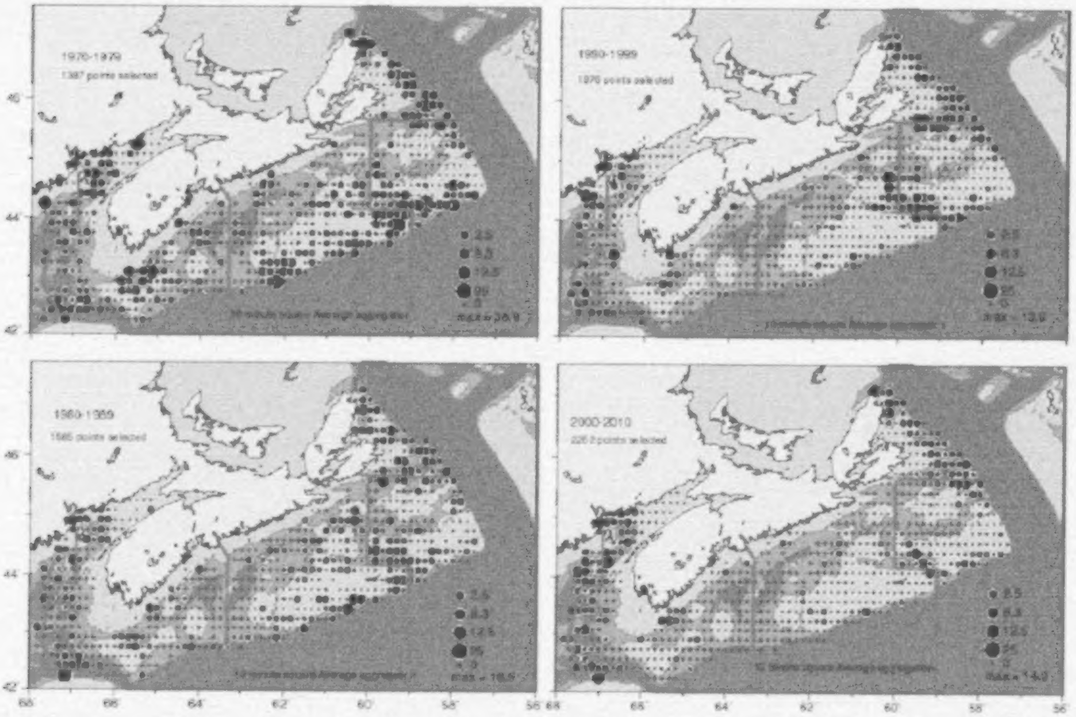


Figure 13. Distribution of Smooth Skate on the Scotian Shelf, part of the Laurentian-Scotian DU, based on summer surveys, 1970-2010, by decade. Dots represent the number of fish caught per tow.

On the eastern Scotian Shelf (Div. 4VW) both adult and juvenile AO decreased after the 1970s. Adult AO stabilized at about 5,000 km^2 since 1987, whereas juveniles have been in a steady decline (Figure 14). The combined AO during the first five years in the time series was 2.7 times greater than the last five years.

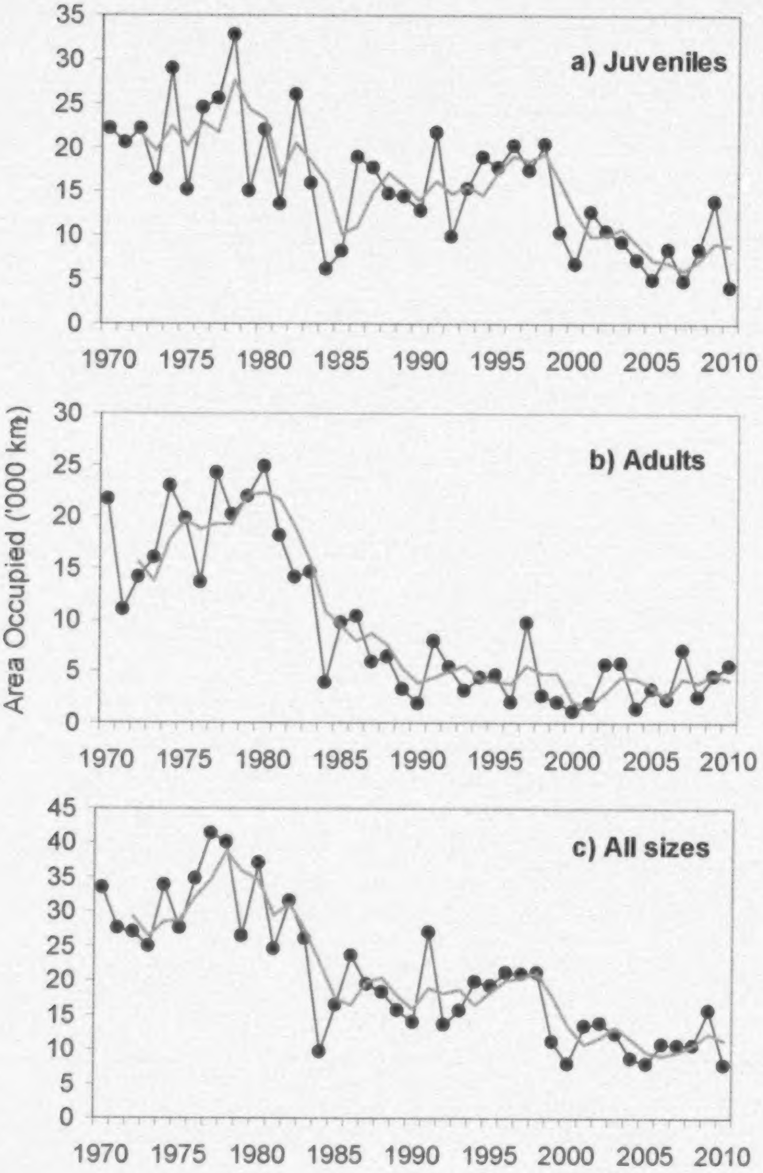


Figure 14. Design-weighted area of occupancy of Smooth Skate for the eastern Scotian Shelf, part of the Laurentian-Scotian DU (Div. 4VW portion). The red line is the 3-year running average.

On the western Scotian Shelf (Div. 4X), the juvenile AO fluctuated without trend, reaching a low in the 1990s. The adult AO in 2000-2010 is 44% of the AO during 1970-1980, although it has been increasing steadily since the low point in the early 1990s. The combined AO declined to 8,000 km^2 in 1989-1992 but has increased since to about 20,000 km^2. The average value of the combined AO during the last five years is nearly the same as in the first five years (Figure 15).

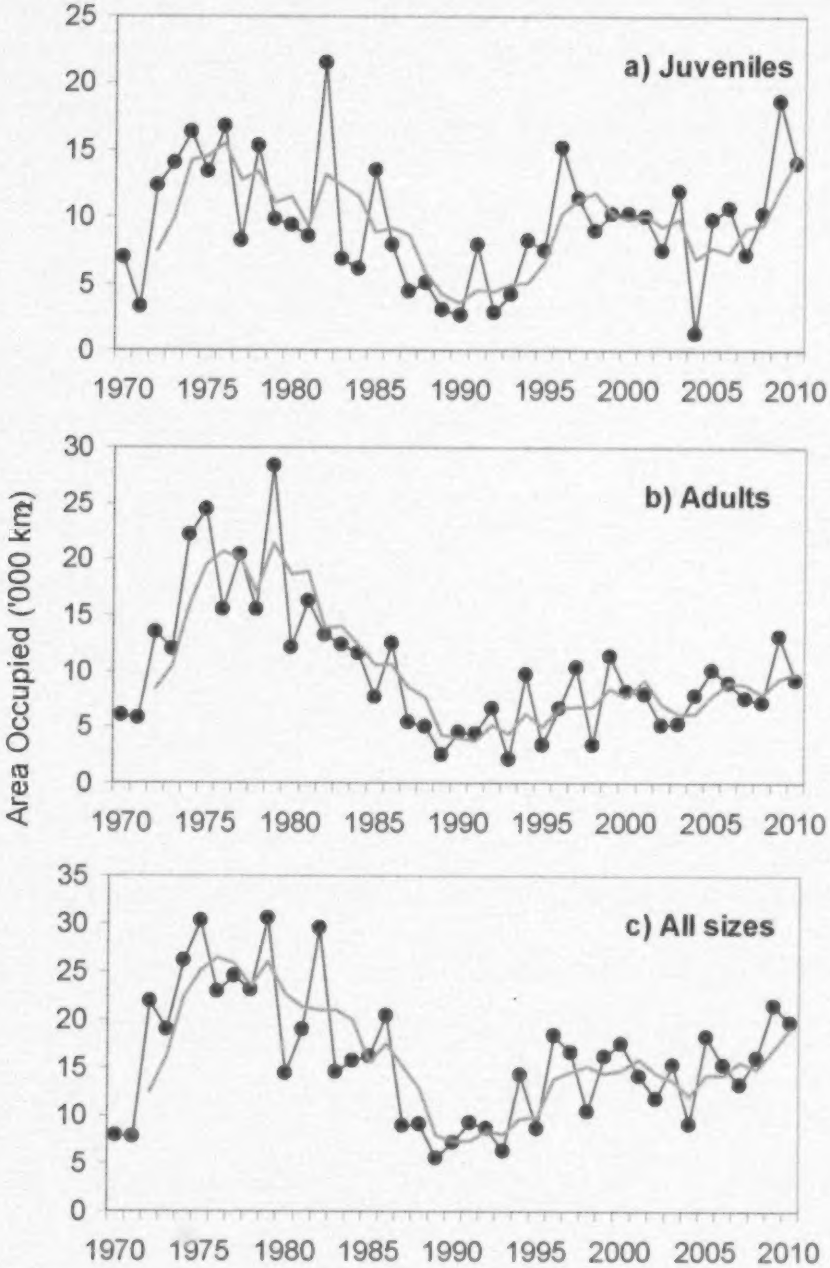


Figure 15. Design weighted area of occupancy of Smooth Skate for the western Scotian Shelf (Div. 4X), part of the Laurentian-Scotian DU. The red line is the 3-year running average.

Georges Bank/Gulf of Maine (Laurentian-Scotian and USA waters)

Smooth Skate straddle the border between Canada and the USA, occupying Georges Bank to the Bay of Fundy (Figure 16). Most of the fish there occur in US waters. On the Canadian side of Georges Bank (Div 5Z), AO has fluctuated without trend since the late 1980s (Figure 17).

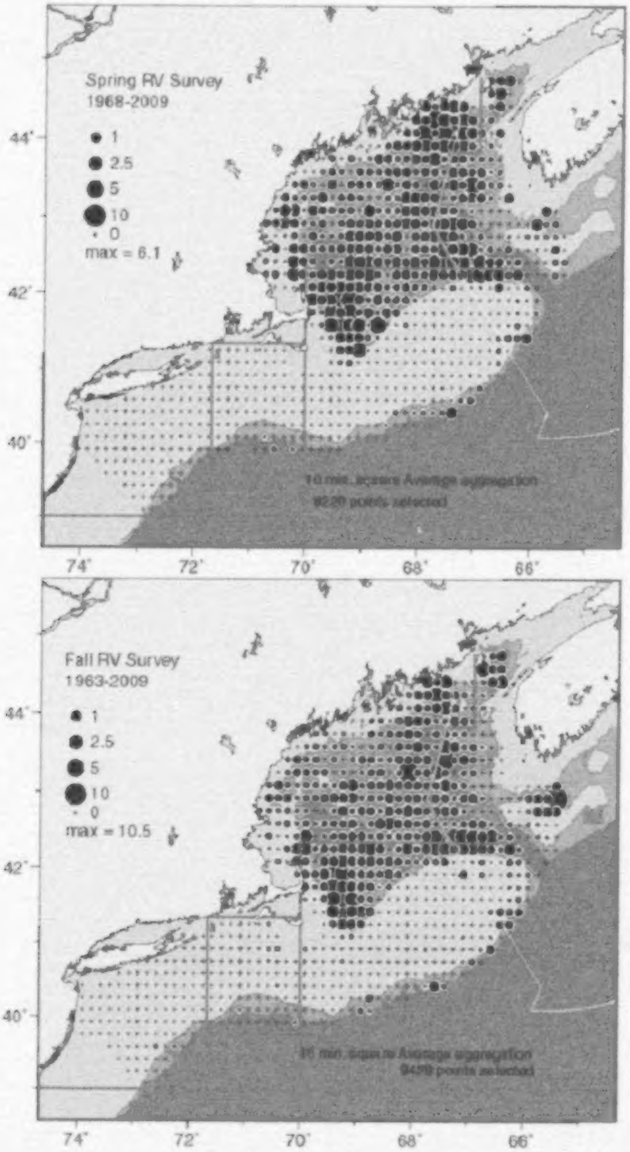

Spring RV Survey
1968-2009
1
2.5
5
10
0
max = 6.1
10 min. square Average aggregation
9220 points selected
Fall RV Survey
1963-2009
1
2.5
5
10
0
max = 10.5
10 min. square Average aggregation
9470 points selected
44°
42°
40°
74°
72°
70°
68°
66°

Figure 16. Distribution of Smooth Skate on the Gulf of Maine and Georges Bank, 1963-2009, based on US surveys. This area straddles the Canada/USA jurisdictions.

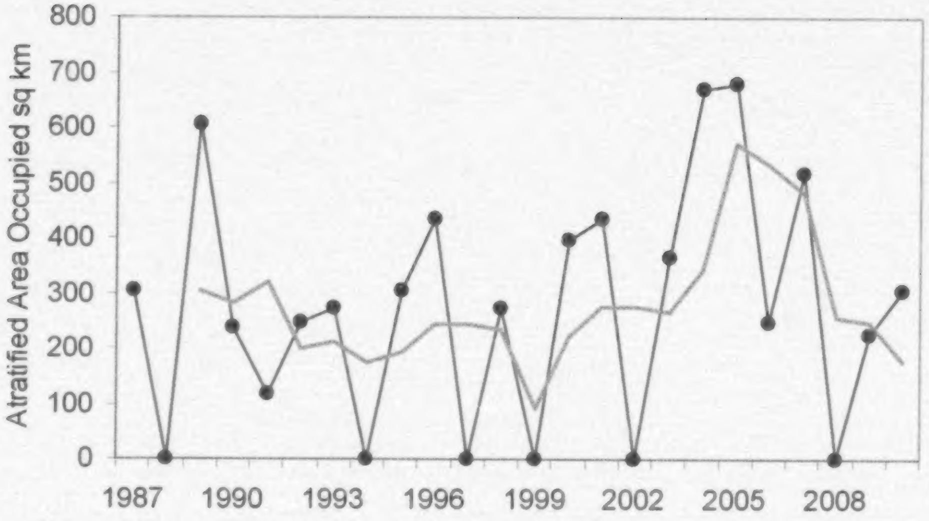


Figure 17. Area of occupancy of Smooth Skates in Div. 5Z on the Canadian portion of Georges Bank. The red line is the 3-year running average.

All Regions, Laurentian-Scotian DU

Since the 1970s, the Laurentian-Scotian DU underwent increases in AO on the southern Grand Banks and northern Gulf of St. Lawrence, fluctuated without trend in southern Gulf and declined on the Scotian Shelf. In 1990-1992 (when all areas of the Laurentian-Scotian DU were sampled), estimated total AO was 65,000 km^2. In 2008-2010, the AO had increased to the highest value in the series, 120,000 km^2.

All Canadian waters combined

It is not possible to quantify changes in area of occupancy in Smooth Skate for all Canadian waters since the early 1970s because data for some regions were not available until later dates. The longest continuous time series of AO is the combination of the Funk Island Deep and Laurentian-Scotian DU. In the period from 1978-1980, the AO of these areas was approximately 155,000 km^2. By the mid-1990s it had declined to ~80,000 km^2. Since then, the AO has increased to 160,000 km^2, very similar to the late 1970s, mainly attributable to an increase in the Laurentian-Scotian DU.

HABITAT

Habitat Requirements

Smooth Skate occurs over a fairly wide range of depths although range is narrower at specific latitudes (Kulka *et al.* 2006). The shallowest/deepest records of this species are 25/1436 m. However, 90% of survey sets containing Smooth Skate occur between 70 and 480 m (Figure 3, upper).

These fish are found over a relatively narrow range of temperatures; the coldest/warmest records are -1.3/15.7° C although only 0.9% of occurrences were associated with bottom temperatures <0° C and 7% with <2° C. The densest concentrations and 90% of survey occurrences were found between 2.7 and 10°C (Figure 3, lower). Fish tend to be found in shallower waters at the southern end of the distribution, with the density peaking at 325 m in the Gulf of Maine (GoM) and 525 m at the Hopedale Channel DU (Kulka *et al.* 2006).

The densest concentrations occur in the troughs surrounding the banks where the temperature is warmer. Relatively narrow temperature distributions may partly explain the unusual disjunct distribution of this species. Much of the banks, the northern Grand Banks and the Magdalen Shallows in the Gulf of St. Lawrence (Dufour *et al.* 2010) are devoid of Smooth Skate because bottom temperatures there are largely <2° C, sandy and shallow. However, the disjunctions also include areas with "suitable" temperatures and depths (at least during certain seasons); along the shelf edge of the Labrador Shelf to Grand Banks, the Cartwright Channel and Marginal Trough of the northeast Newfoundland Shelf. Thus, factors in addition to temperature and depth are influencing the distribution of the species but these are poorly understood.

Feeding studies indicate that Smooth Skate is quite selective in its diet, eating primarily small crustaceans throughout most of its life, and fish only at the largest sizes (McEachran 1973; McEachran *et al.* 1976; Bowman *et al.* 2000; McEachran 2002; González *et al.* 2006). It is not clear whether this further constrains their distribution.

Little is known about benthic structure preferences of Smooth Skate although Bigelow and Schroeder (1953) and McEachran and Musick (1975) reported that it is found mostly on soft mud (silt and clay) bottoms, but also on sand, broken shells, gravel, and pebbles on the offshore banks of the Gulf of Maine. Information on habitat associations is detailed in Packer *et al.* (2003), Kulka *et al.* (2006), Swain and Benoît (2012), Simon *et al.* (2012), and Simpson *et al,* (2012).

Habitat Trends

Long-term temperature conditions at "Station 27", located near the highly depleted Funk Island Deep DU, were generally warmer than average from 1950 until the early 1970s (Figure 4, after Colbourne *et al.* 2010). In 1995-2009, following the decline in the Funk Island Deep DU, remaining fish were in the warmest available places. Suitable temperatures were less extensive during 1985-94, corresponding with a period where Smooth Skate had the smallest distribution. As well, during 1985-94, temperature at depth within the range of Smooth Skates was lower than during other periods and highest during 1995-2007 (see Kulka *et al.* 2006; Colbourne and Kulka 2004). Given that a cooling trend occurred in conjunction with the decline of Funk Island Deep DU Smooth Skate, the species is associated with warmest available temperatures there and fishing pressure apparently remained low during the decline, then temperature changes described above may have affected abundance of the species in the DU. However, area occupied (and abundance) continued to decline from the mid-1990s to the early 2000s even when water temperature warmed. Some recovery in area occupied and density has been observed since and so if temperature has affected the abundance of Smooth Skate in some areas, recovery may lag due to low reproductive potential.

Petrie and Pettipas (2010) noted that temperature in the Emerald Basin generally reflects long-term trends of various parts of the Scotian Shelf, Bay of Fundy and Georges Bank (southern extent of the Laurentian-Scotian DU). The most recent observations show temperatures are near average on the eastern Scotian Shelf and below average in the western Scotian Shelf. The cooling period that occurred there from the late 1970s to the early 1990s may have affected abundance, particularly in conjunction with fisheries.

BIOLOGY

Life Cycle and Reproduction

Development of the young into a fully formed juvenile of about 7-10 cm total length occurs within an egg capsule after it is laid on the bottom. The length of time between extrusion and hatching is unknown but generally for skates, this takes about 1-2 years. McPhie and Campana (2009a) indicated that Smooth Skate produce up to 41-56 egg capsules annually and Simon *et al.* (2012) reported annual fecundity of 100.

Reproduction appears to be widespread throughout the range, with egg cases having been found on the bottom at various times of the year within the various DUs (Simon *et al.* 2012, Simpson *et al.*, 2012). Fully mature females, some containing partially or fully formed egg cases, have also been observed in most parts of the Canadian range including from the Hopedale Channel, Funk Island Deep and Laurentian-Scotian DUs as well as the Flemish Cap (Kulka *et al.* 2006).

Maturity

Size at sexual maturity is similar throughout the range with the exception of the southernmost localities (Table 6). A breakpoint of 47 cm to differentiate Smooth Skate juveniles from mature adults is reasonable for the Canadian part of the range except in the Bay of Fundy, where fish may mature at a slightly larger size, similar to the Gulf of Maine. In Canadian waters, female Smooth Skate mature at an average of 11 years old (Table 6).

Age, Growth, and Size

Age and growth studies for the Gulf of Maine and Scotian Shelf include McEachran (1973), Tsang (2005), Natanson *et al.* (2007), Sulikowski *et al.* (2009), McPhie and Campana (2009b) and Kulka *et al.* (2006) summarized in Table 7. Values of L_0 (length at birth), L_{max} (maximum length) L_{inf}, K (growth rate) and A_{max} (maximum age) from various studies are generally consistent but growth is slower in Canadian waters than in the USA (Table 7).

Kulka *et al.* (2006) reported size range in the Hopedale Channel, Funk Island Deep, Flemish Cap and Laurentian-Scotian DUs, of 7-73 cm, rarely >65 cm, which is likely close to the entire range of sizes found in the population. Size range in the Gulf of St. Lawrence was 10-67 cm and 11-62 cm on the Scotian Shelf. Fish >63 cm were rare and this is similar to asymptotic length, L_{inf}, calculated from the various growth models (Table 7). Mature males have a slightly larger mature mode peaking at 57 cm than females at 52 cm (Kulka *et al.* 2006). This suggests sexually dimorphic growth (e.g. Figure 5).

Generation Time

Generation time is average age of parents of the current cohort calculated as:

$$G = A_m + 1/M$$

If a natural rate of mortality (M) of 0.2 is assumed (as is generally assumed for marine fish) and age at maturity (A_m) is 11 then the generation time is 16 years (Simon *et al.* 2012). Note that there is little confidence in this value for M, and that the generation time of 16 years is probably an underestimate of the pre-exploitation generation time, which is required by IUCN guidelines.

Predation

There is little information regarding predation on Smooth Skate. Indeed, no Smooth Skates were found in an examination of over 156,000 stomachs of 68 species of potential predators, largely from the Scotian Shelf (Simon *et al.* 2012). This species and two other skates in the northwest Atlantic are preyed upon by marine mammals such as grey seals (Benoît and Swain 2011), whereas egg capsules are subject to predation by Atlantic halibut (*Hippoglossus hippoglossus*), goosefish (*Lophius americanus*), Greenland sharks (*Somniosus microcephalus*) and gastropods (Cox *et al.* 1999). It is likely that at least some of these predators prey upon Smooth Skate adults and egg capsules as well.

Physiology and Adaptability

With the exception of work on stress due to capture and post-release mortality (Sulikowski 2011), physiological studies have not been carried out on Smooth Skate. However, the species is consistently found in a relatively narrow temperature range (Figure 3).

Dispersal and Migration

Mark-recapture studies of skates (primarily other species) show average movements of about 100 km, with a small proportion moving up to 440 km (Templeman 1984). This suggests limited dispersal, as is typical of skates (Walker *et al.* 1997; Hunter *et al.* 2005). The complete absence of Smooth Skate between the DUs in 60 years of intense sampling suggests isolation among concentrations. Further, skates produce large eggs (purses) deposited on the bottom, therefore there is little chance for wide dispersion of early stages. Thus, it is unlikely that there would be significant interchange between the DUs. As well, large females showing signs of having spawned have been observed within each of the DUs (see details under Biology), and all DUs contain a broad spectrum of sizes, including juveniles and adults. All this together suggests discreet breeding units. Note that the distribution of Smooth Skate in Canadian waters on Georges Bank is continuous with those in American waters so there is mixing across the border.

Interspecific Interactions

Analyses of nearly 600 stomachs of Smooth Skates caught in winter and summer in DFO surveys off the Scotian Shelf between 1999 and 2008 showed little variation in diet among seasons or areas (Simon *et al.* 2012). The most common prey items were shrimps, arthropods, oregoniids, euphausiids, and crustaceans. These findings match earlier studies in US waters (McEachran *et al,* 1976, Garrison and Link, 2000, Packer *et al.*, 2003) and off Newfoundland (González *et al.*, 2006). Older individuals prey on fishes as well as invertebrates.

The only study that dealt with parasites of Smooth Skate was Randhawa *et al.* (2008) who surveyed tapeworm infestation in the Bay of Fundy. No information on possible impact of the parasites was given.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Fisheries and Oceans (DFO) demersal research trawl surveys form the basis for determining population size and trends for Smooth Skate. The surveys were originally designed to estimate the abundance of the major groundfish species such as Atlantic cod (*Gadus morhua*). However, Smooth Skate is found in a similar set of depths and latitudes. Figure 2c illustrates the demersal survey sets between 1971 and 2009, including those in USA waters. Each dot represents a survey set and each colour delineates regional surveys amounting to more than 100,000 survey sets. The surveys are administered separately by four DFO regions: 1) Newfoundland and Labrador (NL); 2) Quebec; 3) Gulf; and 4) Maritimes. This has led to differences in seasons and years surveyed and in survey trawl gears used, each with different, uncalibrated catchability (see Tables 2-5). Methods are summarized in the following documents: all regions up to 2006 (Kulka *et al.* 2006), Maritimes (Simon *et al.* 2012), Gulf and Quebec (Swain and Benoît 2011), Newfoundland (Simpson *et al.* 2012).

Table 2a. Survey information available from DFO-Newfoundland and Labrador Region research trawl surveys. Various gears have been employed (Yankee-41.5 otter trawl, depicted in brown; Engel-145 otter trawl, blue area; Campelen-1800 shrimp trawl, yellow area) on various vessels. These areas completely encompass the Hopedale Channel, Funk Island Deep and Flemish Cap DUs and a portion of the Laurentian-Scotian DU (Figure 11b).

	NAFO Div. north to south, for each seasonal survey										
	2H	2J	3K	3L	3N	3O	3M	3L	3N	3O	3Ps
Year	Fall	Fall	Fall	Fall	Fall	Fall	Fall/Winter	Spring	Spring	Spring	Spring
1971								■	■	■	
1972								■	■		■
1973								■	■	■	■
1974								■	■		■
1975								■	■	■	■
1976								■	■	■	■
1977		■	■				■	■	■	■	■
1978	■	■	■				■	■	■	■	■
1979	■	■	■				■	■	■	■	■
1980		■	■				■	■	■	■	■
1981	■	■	■	■			■	■	■	■	■
1982		■	■	■			■	■	■	■	■
1983		■	■	■			■				■
1984		■	■	■			■	■	■	■	■
1985		■	■	■			■	■	■	■	■
1986		■	■	■				■	■	■	■
1987	■	■	■	■				■	■	■	■
1988	■	■	■	■				■	■	■	■
1989		■	■	■	■	■		■	■	■	■
1990		■	■	■	■	■		■	■	■	■
1991	■	■	■	■	■	■		■	■	■	■

NAFO Div. north to south, for each seasonal survey											
	2H	2J 3K		3L	3N	3O	3M	3L	3N	3O	3Ps
Year	Fall	Fall	Fall	Fall	Fall	Fall	Fall/Winter	Spring	Spring	Spring	Spring
1992		▨	▨	▨	▨	▨		▨	▨	▨	▨
1993		▨	▨	▨	▨	▨		▨	▨	▨	▨
1994		▨	▨	▨	▨	▨		▨	▨	▨	▨
1995								▨	▨	▨	▨
1996											
1997											
1998											
1999											
2000											
2001											
2002											
2003											
2004											
2005											
2006											
2007											
2008											
2009											

Table 3. Trawl survey information available from DFO Quebec Region in northern Gulf of St. Lawrence (Laurentian-Scotian DU).

Vessel	Length (m)	Year	Month	Gear	NAFO	Coverage	Tow duration (min.)	Tow speed (knots)	Standard tow (nm)	Wing spread (ft)
Gadus Atlantica	73.8	1978-1994 No survey in 1982	Jan.	Engels 145	3Pn, 4RS	Strata > 50 fathoms Estuary not covered Average surveyed area 62,550 km² Range 31,700 to 100,400 km² 3Pn and 4R strata were well covered	30	3.5	1.8	45
Lady Hammond	58	1984-1990	Aug.	Western IIA	4RST	Strata > 50 fathoms 3Pn was not covered, Estuary sparsely covered Average surveyed area 85,300 km²	30	3.5	1.8	41
Alfred Needler	50.3	1990-2005 No survey in 2004	Aug.	Uri Shrimp Trawl	3Pn, 4RS	Addition of shallow strata 20-50 fathoms 3Pn covered from 1993-2003 Average surveyed area 111,300 km² Range 95,070-119,000 km²	24	3	0.8	44
Teleost	63	2004-2010	Aug.	Campelen 1800 Rock Hopper foot gear	4RST	3Pn was not covered Average surveyed area 108,000 km² Range 91,600-116,100 km²	15	3	0.75	55.6

Table 4. Survey information available from DFO Gulf Region in southern Gulf of St. Lawrence (Laurentian-Scotian DU).

Changes in survey vessel:	
E.E. Prince	1971-1985
Lady Hammond	1985-1991
Alfred Needler	1992-2002, 2004, 2005
Wilfred Templeman	2003
Teleost	2004-present
Differences in gear:	
Yankee 36 used by *E.E. Prince*, Western IIA by other vessels	
Differences in fishing procedure:	
Day-only fishing by *E.E. Prince*, 24-hr fishing by other vessels	

Table 5. Summary of main demersal survey data sources for each region. Each line corresponds to a different survey. Refer to Tables 3 and 4 for descriptions of gears used.

DU	NAFO Division	Start Year	Survey Season
Hopedale Channel	2H	1987	Fall
Funk Island Deep	2J3K	1977	Fall
Nose of the Grand Bank	3L	1977	Fall
Laurentian			
Southwestern Grand Banks	3NOPs	1976	Spring
Southern Gulf of St. Lawrence	4T	1971	Fall
Northern Gulf of St. Lawrence	3Pn4RST	1991	Summer
Scotian Shelf	4VWX	1970	Summer
Georges Bank	5Z	1987	Winter

Table 6. Length and age at 50% maturity for Smooth Skate.

Region	DU	50% Maturity				Source
		Male length (cm)	Male age	Female length (cm)	Female age	
Labrador Shelf	Hopedale Channel	47		44		preliminary
Labrador Shelf	Funk Island Deep	49		41		Kulka *et al.* (2006) Kulka *et al.* 2007
Labrador Shelf	Funk Island Deep	49		43		preliminary
Southern Gulf	Laurentian	47		45		Swain and Benoît (2011)
Scotian Shelf	Laurentian	57	10	54	9.5	Kulka *et al.* (2006)
Scotian Shelf	Laurentian	50	11.7	47	10.1	McPhie and Campana 2009a
Scotian Shelf	Laurentian	49.8		47.2		Simon *et al.* (2011)
Gulf of Maine	USA	56	9	54	9	Sosebee (2005) Sulikowski *et al.* (2007a, b, c) Kneebone *et al.* (2007) Sulikowski *et al.* (2009)

Table 7. Growth parameters of Smooth Skate. L_0 is size at hatch (total length, cm), L_{max} is largest observed size, L_{inf} is theoretical largest size from the growth model (either von Bertalanffy or Gompertz), k is the growth coefficient, and A_{max} is the oldest observed fish.

DU	Region		L_0	L_{max}	L_{inf}	K	A_{max}	Source
Laurentian (von Bert)	Grand Banks	Male						Kulka *et al.* (2006)
		Female						
		Combined	7.0[1]	73.0	59.3	0.16	17	
Laurentian (von Bert)	Scotian Shelf	Male	10.7	56.0	57.1	0.15		McPhie and Campana (2009b)
		Female	11.7	51.0	64.7	0.10		
		Combined	11.1	56.0	60.7	0.12	15	
Laurentian (Gompertz)	Scotian Shelf	Male	11.9		53.3	0.25		McPhie and Campana (2009b)
		Female	12.1		54.4	0.21		
		Combined	12.0		54.3	0.22		
USA (von Bert)	*Gulf of Maine*	*Male*	*11.0*		*75.4*	*0.12*	*14*	Natanson *et al.* (2007)
		Female	*10.0*		*69.6*	*0.12*	*15*	
		Combined						

[1] Smallest observed individual.

The surveys employ a stratified random design based on depth and latitude (Doubleday 1981; Brodie 2005). Estimates of survey abundance were calculated using the method of areal expansion by multiplying the average number of Smooth Skate caught per tow within each stratum by the number of trawlable units for the respective stratum. The strata estimates are then summed over the entire survey area (Bishop 1994; Kulka *et al.* 2006). These population abundance estimates can be either left unadjusted for gear and spatial changes or adjusted if relevant comparative trawling information is available.

Catchability (q) of most demersal fish in the surveys is thought to be <1 because fish escape the passing nets. This is particularly true for skates, which can pass underneath the gear and for small individuals that pass through the trawl mesh. Catchability has not been estimated for Smooth Skate but survey abundance estimates presented here are considered minimum estimates of population size, well below the true value.

The type of survey gear greatly influences the proportions of the size of fish captured as well as overall catchability at any size and this confounds any comparative analyses or combination of the data among regional surveys (Benoît and Swain 2003). The Laurentian-Scotian DU is most affected as it straddles all DFO regions except Central and Arctic.

The estimates of current minimum trawlable abundance were taken as the mean of the last three years of survey data available. Thus, they are not impacted by gear changes that occurred in some surveys in 1996. For analysis of trends in abundance of adults, Smooth Skate >=48 cm total length were considered mature (refer to section on Maturity).

Abundance

Smooth Skate was the 16th most commonly encountered demersal fish species over the long term, based on all survey results combined. It was also the 2nd most common skate species after thorny skate, indicating that it is a widespread and important component of the demersal fish assemblage of Atlantic Canada.

The following sections provide minimum estimates of abundance for the last three years sampled. Differences among regions and DUs in survey methods prevent direct comparison of abundance, and they also preclude calculation of absolute estimates, as opposed to the minimum numbers presented here. Hopedale Channel and Funk Island Deep estimates are based on NL Region fall surveys. Laurentian estimates are based on a combination of data from the various regions that surveyed that area.

Hopedale Channel DU

The Hopedale Channel DU was sampled sporadically. The current minimum abundance estimate (average for 2006, 2008 and 2010) is 3.03 million individuals, about 5% of which are considered mature (Table 8). However, in this most northerly DU, it is possible that Smooth Skate may mature at a smaller size and if so, there would be a larger proportion of adults.

Table 8. Estimates of recent minimum trawlable abundance derived from Fisheries and Oceans Canada demersal trawl surveys. Reported abundances are the mean of the last three years that a particular survey was conducted. Survey gear is specified below the area. Abundance in the Nose of the Grand Bank DU is unknown but very low.

Area	Adults	Juveniles	Total	% adults
Hopedale (Campelen)	152,148	2,882,000	3,034,148	5%
Funk (Campelen)	320,104	785,086	1,105,190	29%
Laurentian-Scotian				
Grand Bank (Campelen)	1,407,900	2,313,100	3,721,000	38%
Northern Gulf (Campelen)	3,482,552	29,103,858	32,586,410	11%
Southern Gulf (Western IIA)	47,869	313,384	361,253	13%
East Scot. Shelf (Western IIA)	179,522	516,762	696,284	26%
West Scot. Shelf (Western IIA)	420,646	1,162,706	1,583,352	27%
Georges Bk (Western IIA)	165,779	208,521	374,300	44%
Laurentian all	5,704,268		39,322,599	15%
All areas	**6,176,520**	**37,285,417**	**43,461,937**	**14%**

Funk Island Deep DU

The minimum abundance estimate for the Funk Island Deep DU Smooth Skate (average 2008-2010) for all sizes is 1.1 million, 29% (0.3 m) of which are considered mature (Table 8). This represents only 20% of past numbers; the average abundance estimate for mature and immature individuals at the peak in 1978-1980 was 5.3 million fish. However, given the higher catchability for the Campelen trawl used in the latter period vs. the Engel trawl used earlier, the proportion of remaining fish would actually be smaller, considerably lower than 20%.

Nose of the Grand Bank DU

Seventy-seven percent of this region lies outside Canada's 200 mile limit. Estimates of minimum biomass are not available.

Laurentian-Scotian DU

For the Laurentian-Scotian DU in total, the current (2008-2010) minimum trawlable abundance estimate is 37.4 million individuals of which 5.7 million (14%) are considered mature (Table 8). Five different surveys were used to evaluate this DU (see Table 5) and the various regional surveys used different gears with different and uncalibrated catchability. Nonetheless, the numbers provided for the Laurentian-Scotian DU represent a minimum estimate of current abundance for Smooth Skate. Refer to Table 8 for a breakdown by region and mature/immature.

All Canadian waters combined

Conservatively, the minimum trawlable abundance estimate for Smooth Skate in all Canadian waters is 44 million individuals, 6.2 million of which are mature, although actual numbers are likely considerably higher due to imperfect catchability in the surveys and the lack of surveys in a part of the Laurentian Channel, where density is thought to be high.

Fluctuations and Trends

Trends in abundance are based on the most comprehensive survey from each area within a DU/region (Kulka *et al.* 2006). Rates of change were estimated using linear regression after natural log-transformation. These models assume the change in abundance can be adequately described by a smooth curve, which is not always the case. Where populations fluctuated, segments of the trend based on change in trajectory were also analyzed to better reflect population trajectory.

Hopedale Channel DU

High variance and intermittent surveys in this area make it difficult to determine trend in abundance. Adults and juveniles were caught in lower numbers before 1995 than in recent years (Figure 18). However, the change in survey gear in 1995 has likely contributed to the higher rates observed in later years. The limited data suggest that Smooth Skate in the Hopedale Channel DU may have increased or fluctuated without trend.

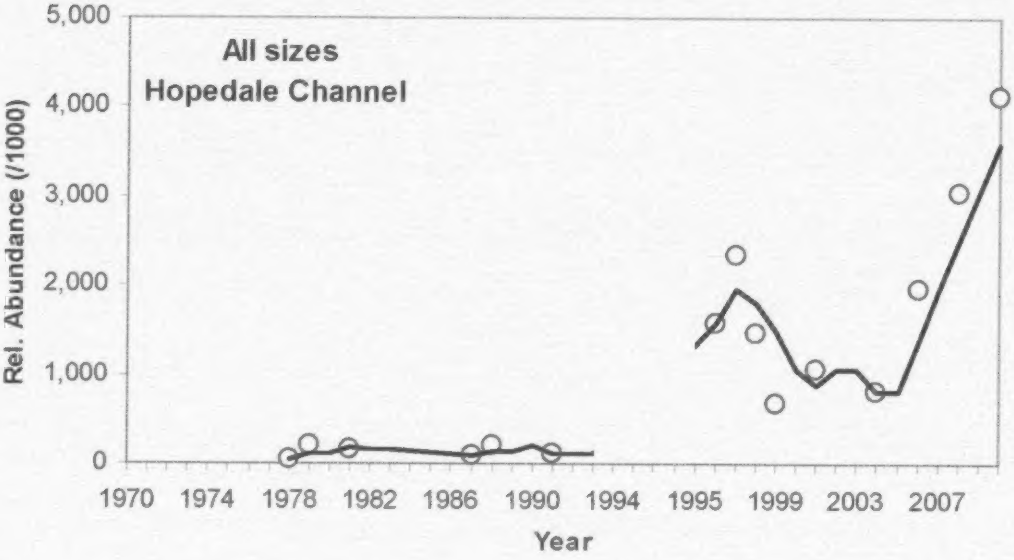


Figure 18a. Relative abundance of Smooth Skate of all sizes from the Hopedale Channel DU. Solid line is a three-year running average. The break in the solid line divides Engel from Campelen estimates.

Funk Island Deep DU

Decline rates are calculated for two periods, 1977 to 1994, when Engel survey gear was used and 1995 to 2009 when Campelen gear was used (no information on staged fish was available for 2010). Differences in catchability of these two gears preclude examination of the survey series as a whole. However, the decline ceases near the time of the gear change and thus it makes a logical split in the series.

The 5-fold increase in both juvenile and adult abundance in the first year of the survey, between 1977 and 1978, is too large to be biologically feasible, an artifact of the survey (Figure 19a). Abundance peaked in the late 1970s, followed by a steep decline in the 1980s. For mature adults, the decline rate from 1977 to 1994 was 94% and from 1995 to 2009, the rate of increase was 166% (Table 9). Note that the latter increase is from the low point at the end of the previous survey series: the fish were still at less than 20% of the abundance recorded at their peak in the late 1970s. Juveniles declined from 1977 to 1994 by 90%. From 1995-2009, their numbers increased by 48%. Note that in the latter time period, r^2 was low and p-value was >0.01, indicating that the natural log model is a poor fit for the fluctuating trend. Figure 19 indicates that the steep decline, for both juveniles and adults, had ceased in the early 2000s. Juveniles have increased since but there has been little change in the adults, with abundance remaining very low in comparison to the start of the series.

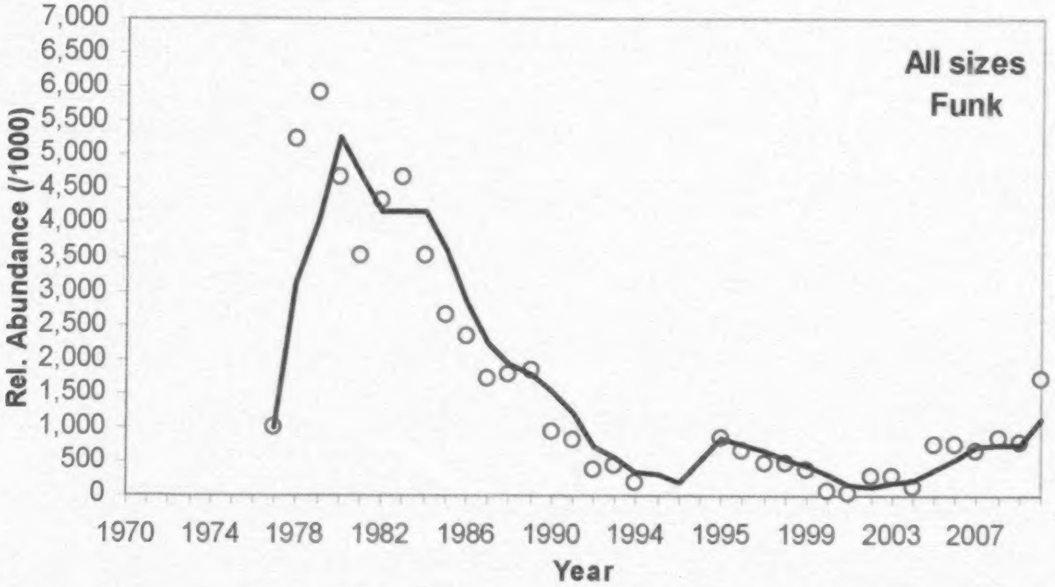


Figure 19a. Relative abundance of Smooth Skate from the Funk Island Deep DU. The break divides Engel from Campelen estimates.

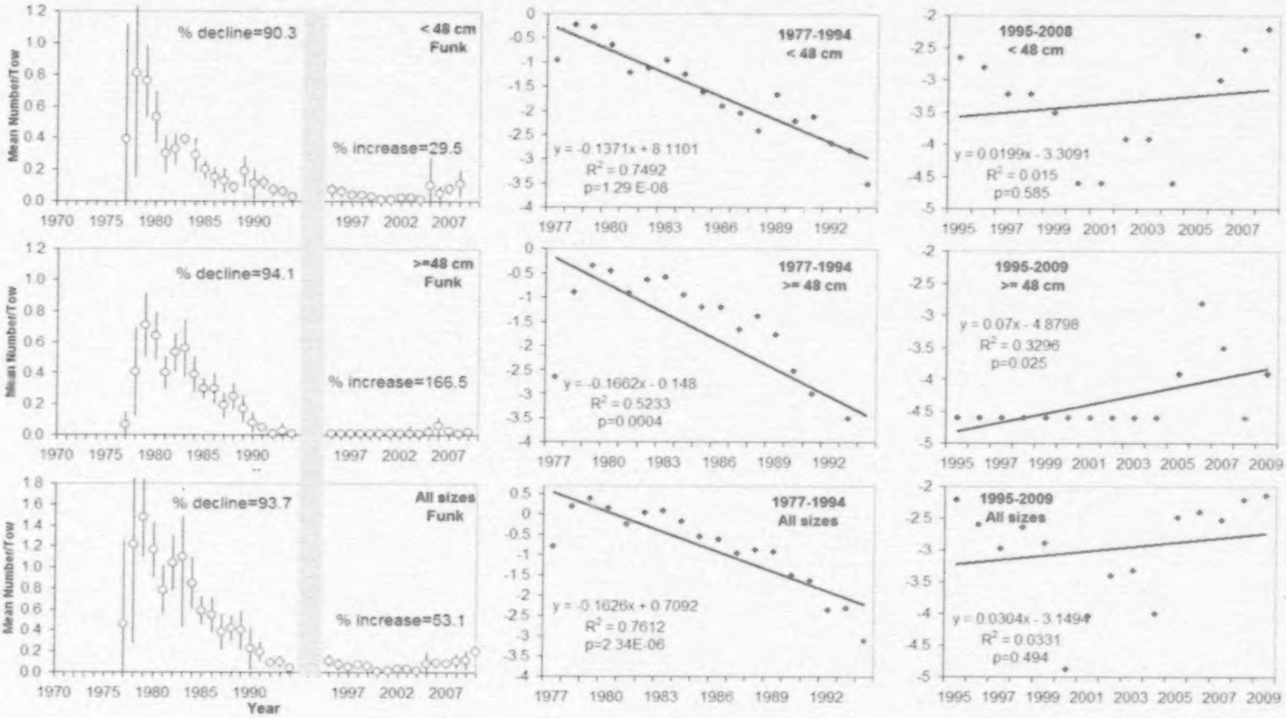


Figure 19b. Mean number per tow of Smooth Skate juveniles (top row), adults (middle row) and all sizes combined (bottom row) from the Funk Island Deep DU. Error bars represent 2 SD. The grey bar divides Engel from Campelen estimates. During the 2010 surveys, fish were not measured, thus juveniles and adults are not distinguished for that year. Ln transformed data are plotted for two periods when the different survey gears were used.

Table 9. Estimated changes in Smooth Skate populations by proposed DU and region in Canadian waters. Annual rates of change and absolute change are shown over the time period surveyed. Data are not available to calculate decline rates for the Hopedale Channel DU. Gen. = # of generations based on generation time of 16 years.

DU	Period of change	All individuals	Mature individuals	Immature individuals	Gen.
Hopedale Channel *(Div. 2H)*		Unknown - likely fluctuation without trend, currently high, max. in 2008			
Funk Island Deep *(Div. 2J3K, part of Div. 3L)*	Survey Engel (1977-1994)	-93.7%	-94.1%	-90.3%	1.06
	Annual change	-15.0%	-15.3%	-12.8%	
	Survey Campelen (1995-2009)	53.1%	166.4%	29.5%	0.88
	Annual change	3.1%	7.3%	3.1%	
Laurentian-Scotian					
Southwest Grand Banks (Div. 3LNOPs)	Survey Engel (1975-1995)	-47.6%	-41.7%	-47.9%	1.25
	Annual change	-2.7%	-2.7%	-3.2%	
	Survey Campelen (1996-2010)	66.7%	96.1%	57.0%	0.88
	Annual change	3.7%	4.9%	3.3%	
Northern Gulf of St. Lawrence (Div. 4RS)	Survey change (1991-2010)	144.2%	84.3%	155.6%	1.19
	Annual change	4.8%	3.3%	5.1%	
Southern Gulf of St. Lawrence (Div. 4T)	Survey change (1971-2010)	29.7%	-65.1%	223.5%	2.44
	Annual change	0.7%	-1.7%	3.1%	
Scotian Shelf (Div. 4VWX)	Survey change (1970-2010)	-77.0%	-80.0%	-49.3%	2.50
	Annual change	-1.9%	-3.9%	-1.7%	
Georges Bank (Div 5Z)	Survey change (1987-2010)	27.1%	n.a.	n.a.	1.44
	Annual change	1.2%	n.a.	n.a.	

Nose of the Grand Bank DU

Only 23% of the Nose of the Grand Bank DU abundance occurs within Canadian waters, it has been poorly sampled and thus a time series of abundance is not available.

Laurentian-Scotian DU

Abundance trends varied widely within different regions of this DU. However, based on the most recent estimates of numbers of fish in Table 8, along with the trends that have led to them (Table 9), it is possible to get an overall impression of the relative weight that should be given to each region according to changes since the start of each time series. The caveats about different catchabilities of sampling gear need to be kept in mind.

Southwest Grand Banks

Population abundance (all sizes of fish) fluctuated without trend up to the mid-1990s and has increased since (Figure 20a). Calculations of trends in Table 9 start in 1975 rather than in 1970 to avoid years where not all areas were sampled (Table 2). Adults declined by 41.7% from 1975 to 1995, but increased by 96.1% from 1996-2010. Juveniles declined from 1975 to 1995 by 47.9%, and increased from 1995-2010 by 57% (Table 9). The trends are sensitive to two (low) years, 1993 and 1994. If they are removed from the series the decline rate flattens to zero in 1975-1995 for juveniles and adults. At the start of the time series, these fish appear to have been less abundant than in the Northern Gulf of St. Lawrence and in the Scotian Shelf.

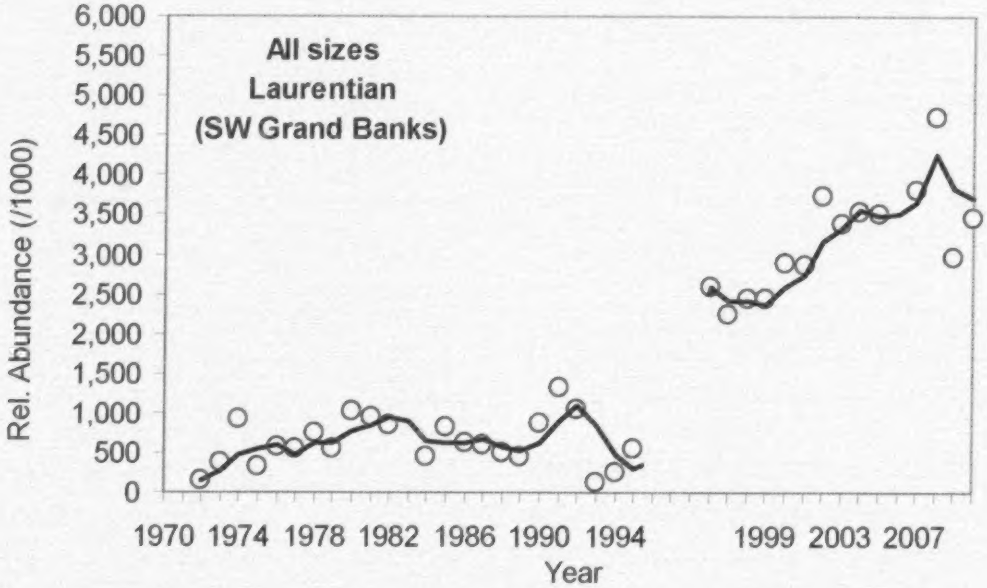


Figure 20a. Relative abundance of Smooth Skate from the Laurentian-Scotian DU, southwest Grand Banks Region. The solid line is the 3-year running average. The break in the solid line divides Engel from Campelen estimates.

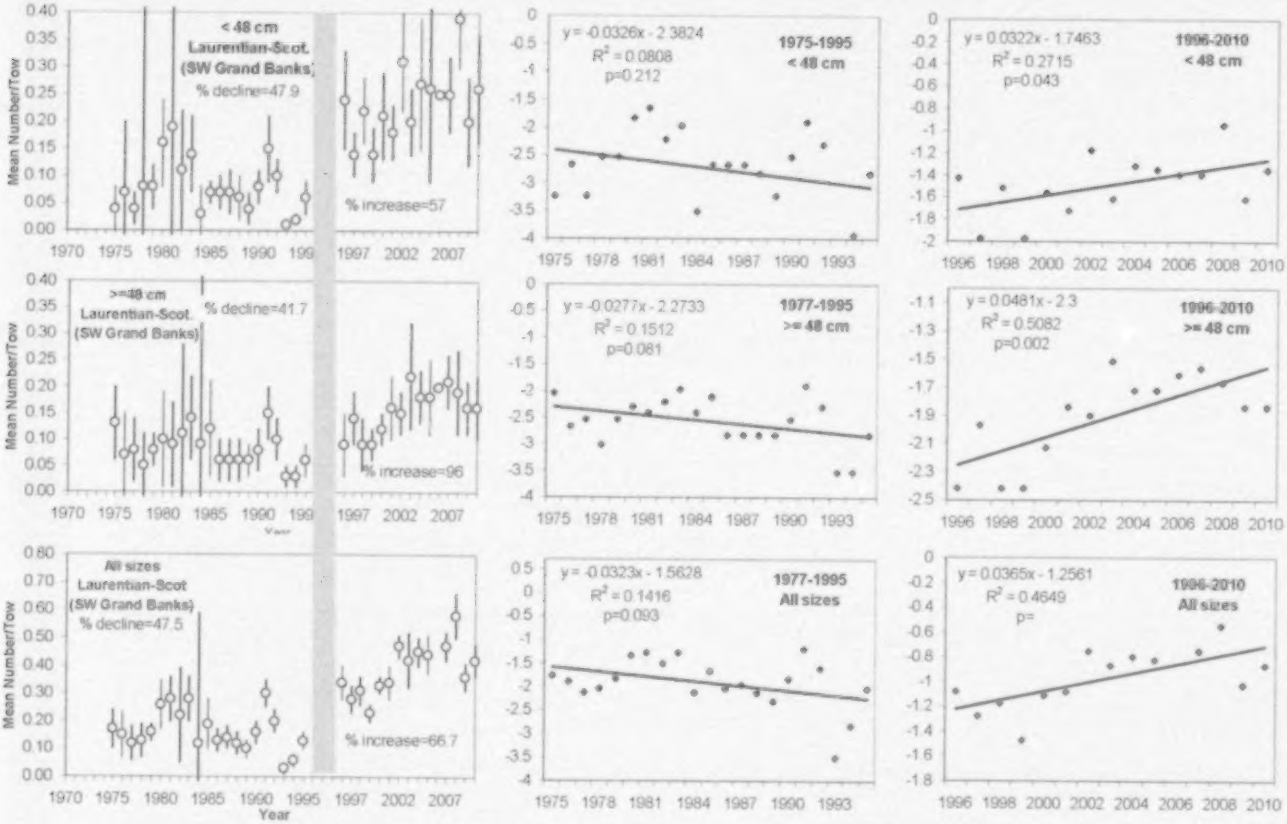


Figure 20b. Mean number per tow of Smooth Skate juveniles, adults and all sizes combined from the Laurentian-Scotian DU (southwest Grand Banks). Error bars represent 2 SD. The grey bar divides Engel from Campelen estimates. During the 2010 surveys, fish were not measured, thus juveniles and adults are not distinguished for that year. Ln transformed data are plotted for two periods when the different survey gears were used.

Northern Gulf of St. Lawrence

During two separate surveys, 1978 and 1994 (Figure 21a) then 1985 to 1991 (Figure 21b) Smooth Skate fluctuated without trend (Bourdage *et al.* 2003). Since 1991, abundance has increased (Figure 21c). For mature adults, the rate of increase from 1991 to 2010 was 84%. For juveniles, the rate was 155%. The high variance, low r^2 and marginal p-values should be noted. This area contains the largest numbers of Smooth Skate within the Laurentian-Scotian DU and highest densities (along with Div. 3Ps), indicating that the population is centred in the Laurentian Channel.

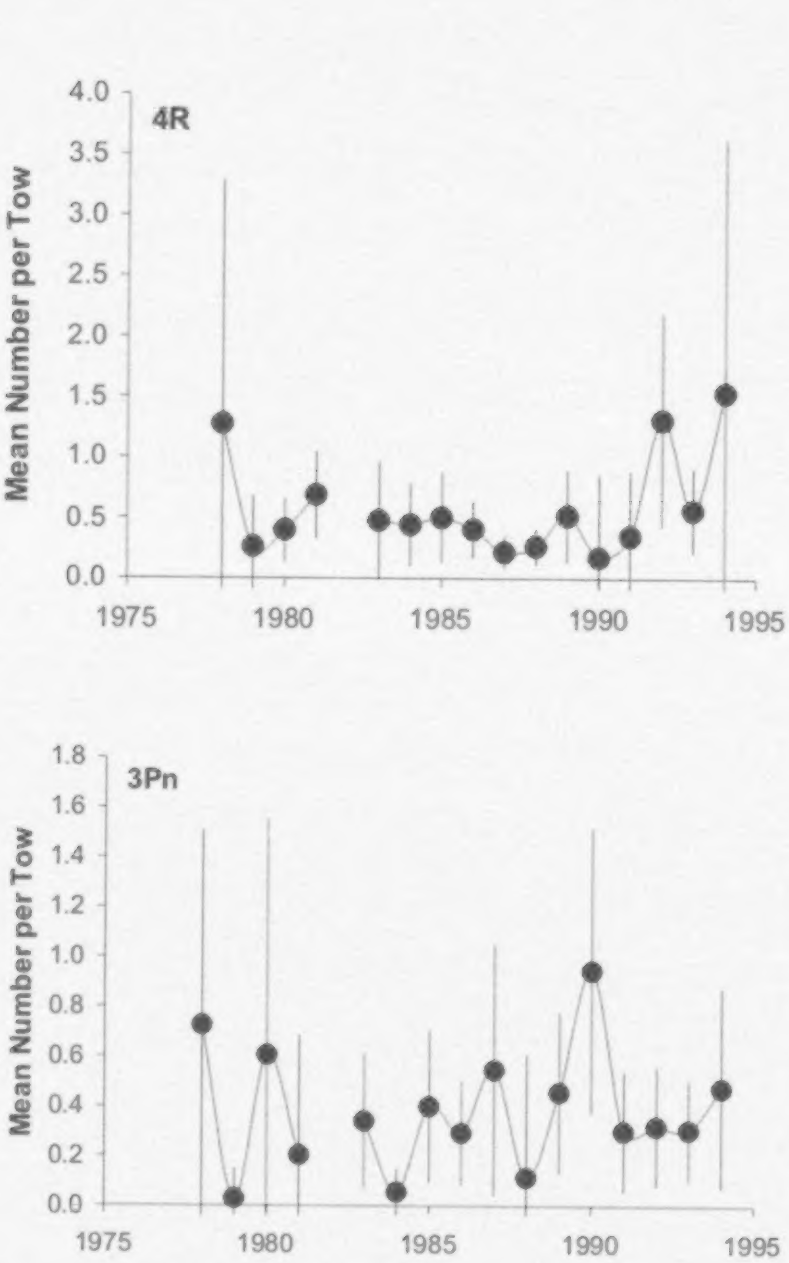


Figure 21a. Catch rates in the northern Gulf of St. Lawrence (Div. 4R and 3Pn) for Smooth Skate in the winter *Gadus Atlantica* survey of the northern Gulf of St. Lawrence. Circles show the stratified mean catch rate. Error bars represent upper and lower 95% confidence limits (from Kulka *et al.* 2006).

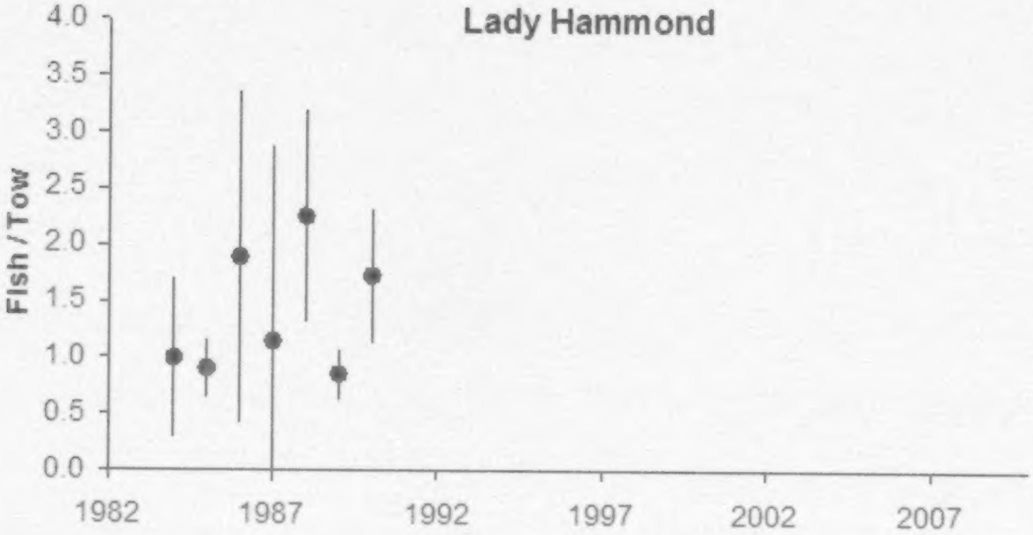


Figure 21b. Mean number per tow for Smooth Skate from the Laurentian-Scotian DU, northern Gulf of St. Lawrence Region, *Lady Hammond* survey (see Table 3 for area surveyed). Error bars represent upper and lower 95% confidence limits.

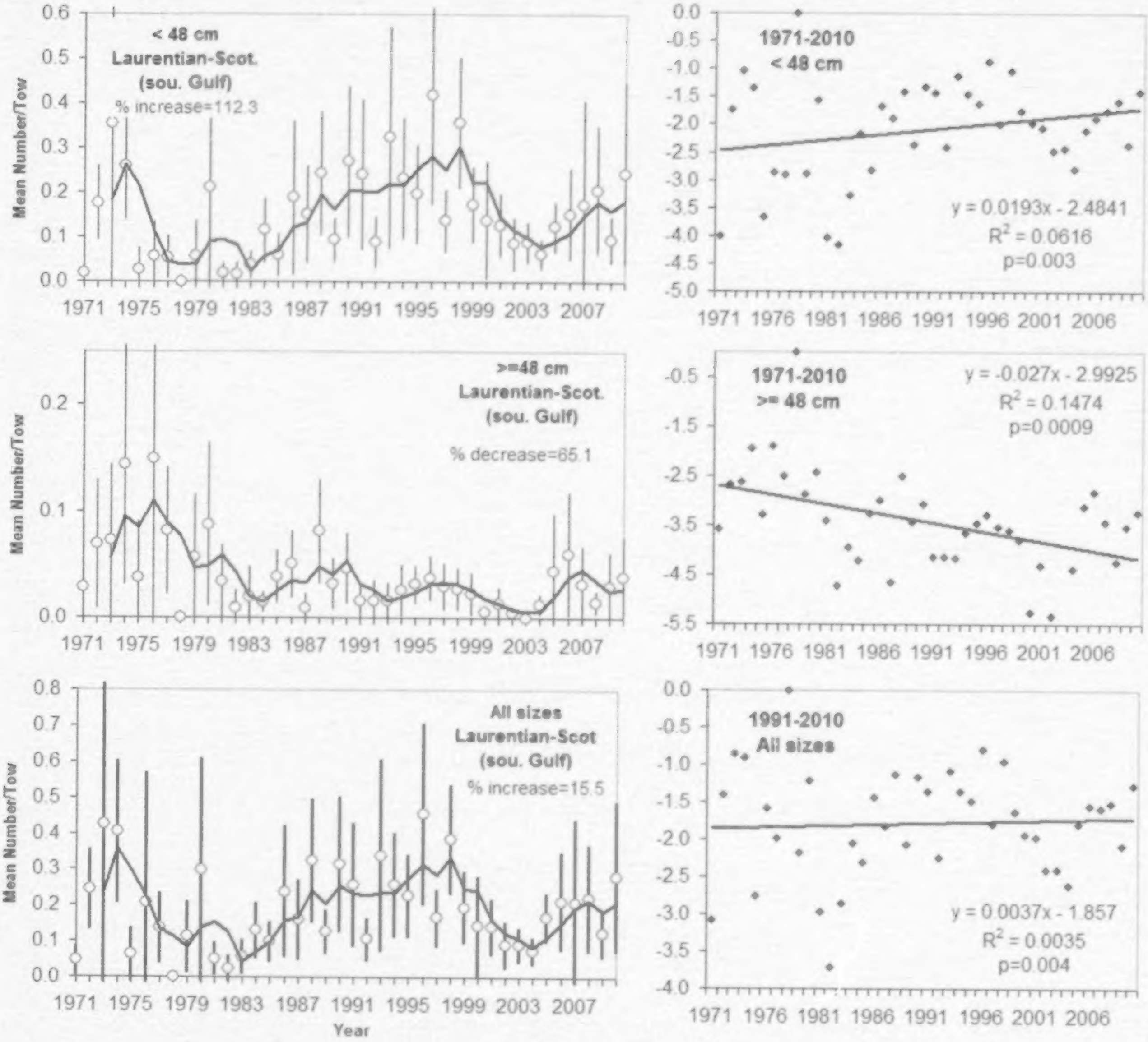


Figure 21c. Mean number per tow for Smooth Skate juveniles and adults from the Laurentian-Scotian DU, northern Gulf of St. Lawrence Region. Error bars represent upper and lower 95% confidence limits. Ln transformed data are plotted to the right.

Southern Gulf of St. Lawrence

During 1971-2010 total abundance estimates fluctuated widely but current abundance is near the long-term mean (Figure 22a). Juveniles fluctuated around a long-term mean, peaking in the early 1970s and the late 1990s while adults underwent a decline in the mid-1970s but have increased since the early 2000s (Figure 22b). During 1971-2010, the rate of increase was 223% over 39 years for juveniles and the decline was 67% for adults (Table 9).

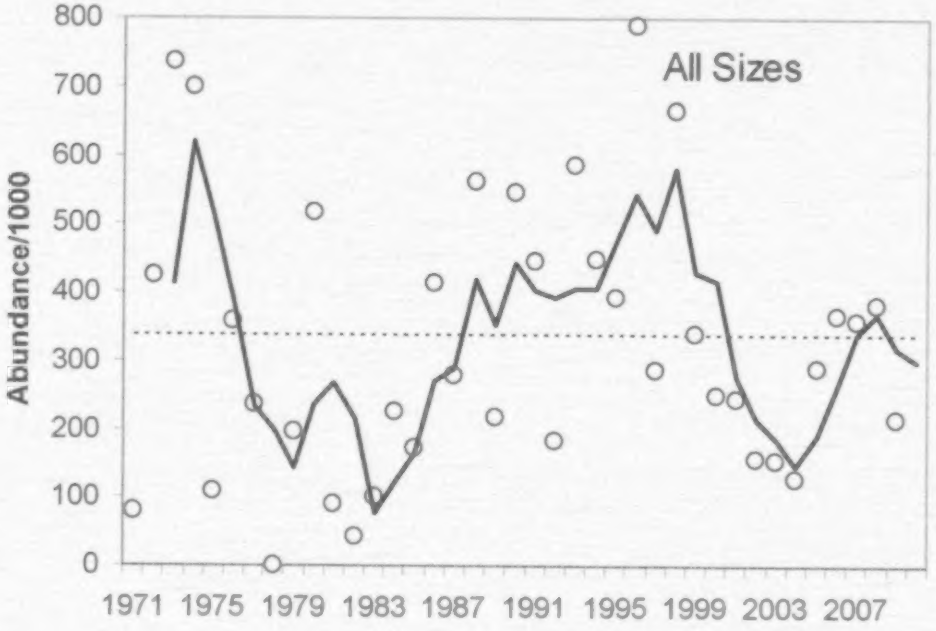


Figure 22a. Relative abundance (per 1,000 tows) of Smooth Skate of all sizes from the Laurentian-Scotian DU, southern Gulf of St. Lawrence Region. The line is the three-year moving average. The horizontal dotted line is the long-term mean.

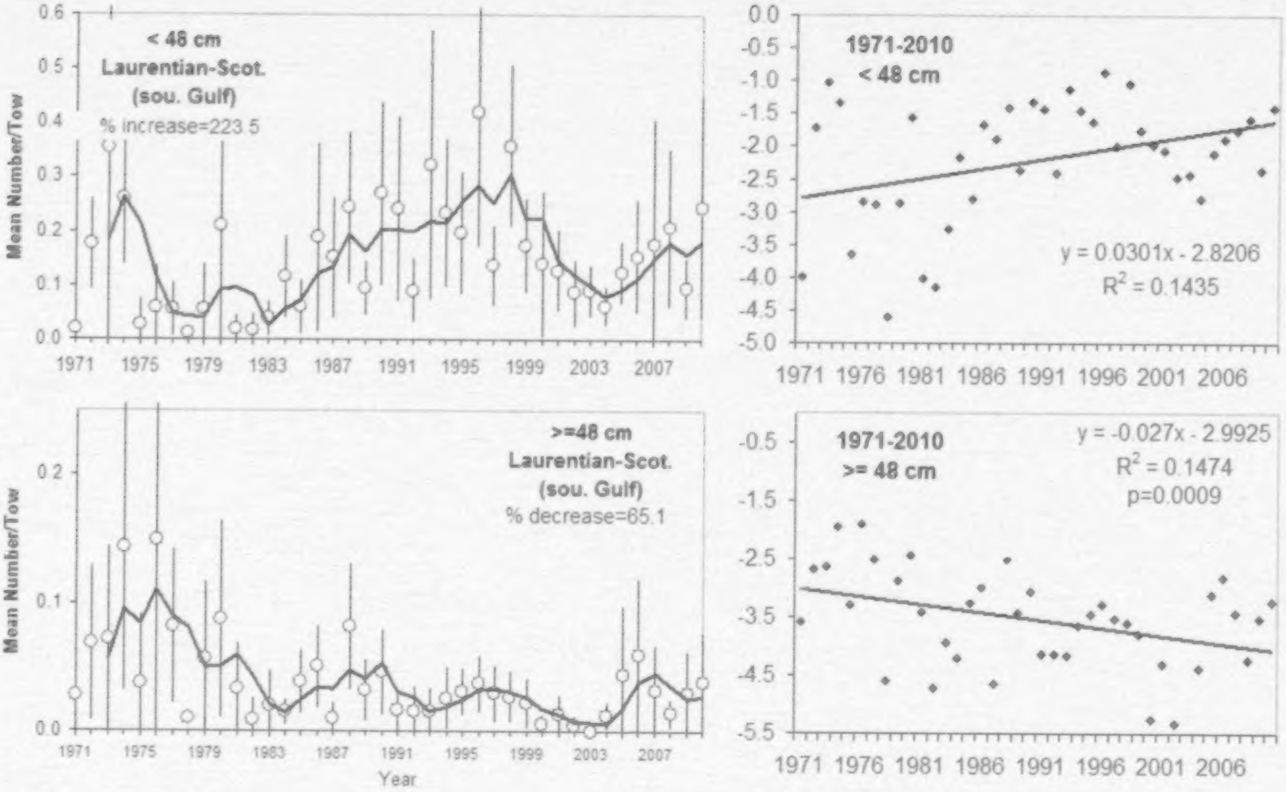


Figure 22b. Relative abundance of Smooth Skate juveniles < 48 cm and adults >= 48 cm from the Laurentian-Scotian DU, southern Gulf of St. Lawrence Region. Error bars represent upper and lower 95% confidence limits. The horizontal dotted line is the long-term mean.

Calculating rate of decline over the entire 39 years is problematic because the trends are complex and fluctuating – the model does not fit the data. For juveniles, although the model indicates a 224% increase, an objective evaluation of the graph suggests that the trend fluctuated and abundance was about the same at the start and end of the series. Influencing the model were the low values observed in the late 1970s to early 1980s, followed by an increase and peak in the late 1990s. For adults, regression of the log values for 1971 to 2002 when abundance reached a low and 2004 to 2010 when abundance started to increase would be more realistic. Note that 2003 is removed from the log regressions as it was zero in that year. Rate of decline for adults during 1971-2002 was 65%, and rate of increase during 2004-2010 was 35%. This indicates that for this component of the Laurentian-Scotian DU, the decline has ceased.

Scotian Shelf

Historically, this region had the largest number of Smooth Skates among the regions surveyed in the Laurentian-Scotian DU. Abundance declined from the 1970s to a minimum around 1990, increased in the 1990s, and has fluctuated near the long-term average since (Figure 23a). From 1970 to 2010, adults declined at a rate of 80% over the 40 years (Figure 23b, Table 9). Juveniles declined by 49.3% over the survey time series. For all sizes combined, the decline was 77% (Table 9).

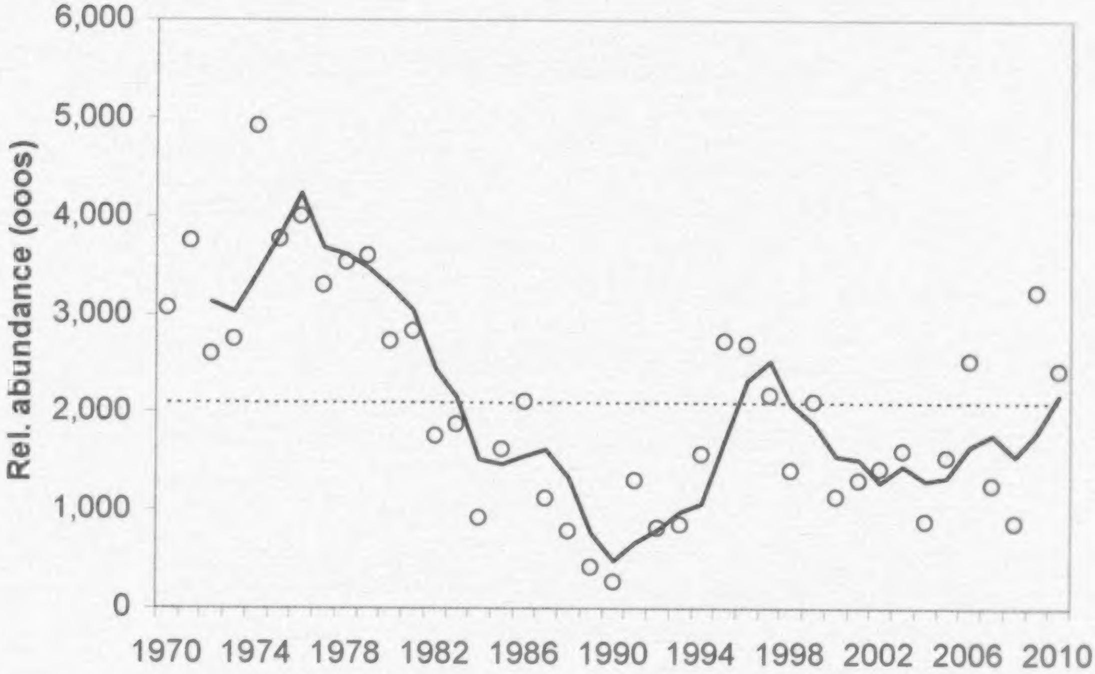


Figure 23a. Relative abundance of Smooth Skate adults and juveniles combined from the Laurentian-Scotian DU, Scotian Shelf (Div. 4VWX). The horizontal dotted line is the long-term mean.

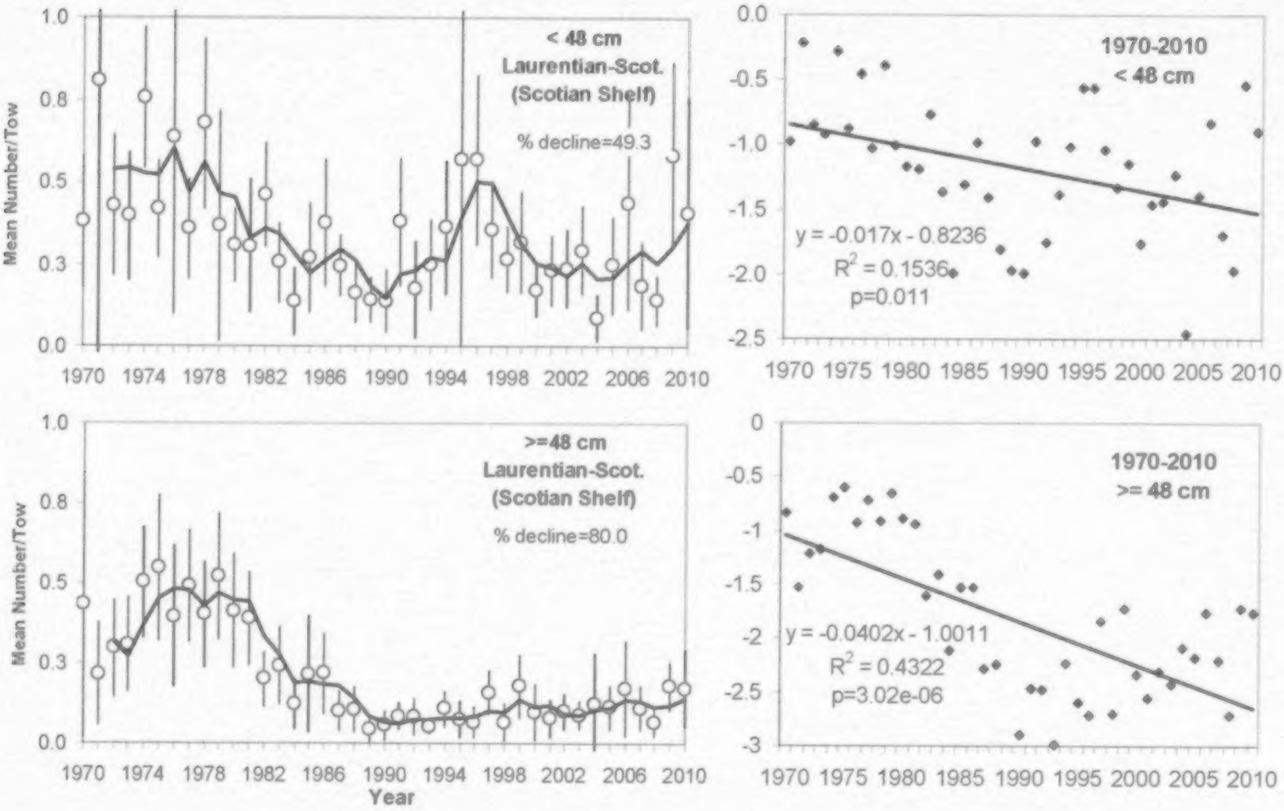


Figure 23b. Mean number per tow of Smooth Skate juveniles and adults from the Laurentian-Scotian DU, Scotian Shelf (Div. 4VWX). Error bars are ± 2 SD.

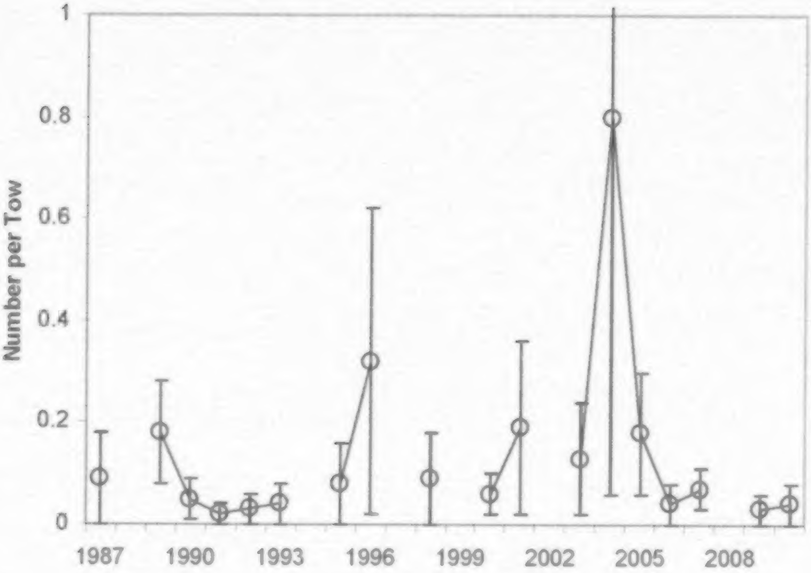


Figure 24. Number per tow of Smooth Skate from the Georges Bank, Canadian sector. Error bars represent upper and lower 95% confidence limits.

An alternative analysis that better fits the data is to calculate decline rate of adults during the period when they underwent the decline, then a rate thereafter when the population was increasing. Adult decline rate from 1970-1989 was 81.9%. Thereafter, the rate of increase was 95.9%. Although the population abundance remains low relative to the 1970s, the decline ceased in the late 1990s. The proportion of mature individuals was higher during the 1970s to the 1990s, averaging 50%, dropping to 30% after the early 1990s.

Georges Bank (Canada)

This area is contiguous with USA distribution and represents a small proportion of the total. Abundance estimates were generally low and adults did not show a significant long-term trend on Georges Bank (Table 9).

Entire Laurentian-Scotian DU

The Laurentian-Scotian DU accounts for 90% of the estimated abundance and 70% of the area in Canada for Smooth Skate. Overall numbers have likely been increasing in recent years. The southwest Grand Banks and northern Gulf encompassing the Laurentian Channel comprise the centre of abundance for Smooth Skate today. There, adults have increased but have declined in the southern Gulf of St.

Lawrence (the smallest component of the Laurentian-Scotian DU) and the Scotian Shelf. It is not clear what has caused the trends to differ among areas. Note that the survey gears in the southern Gulf and eastern Scotian Shelf have a lower catchability than those in the other regions.

Georges Bank (USA)

Figure 25 shows that the USA abundance of Smooth Skate on Georges Bank/Gulf of Maine has been stable or increasing since the late 1970s following an earlier decline.

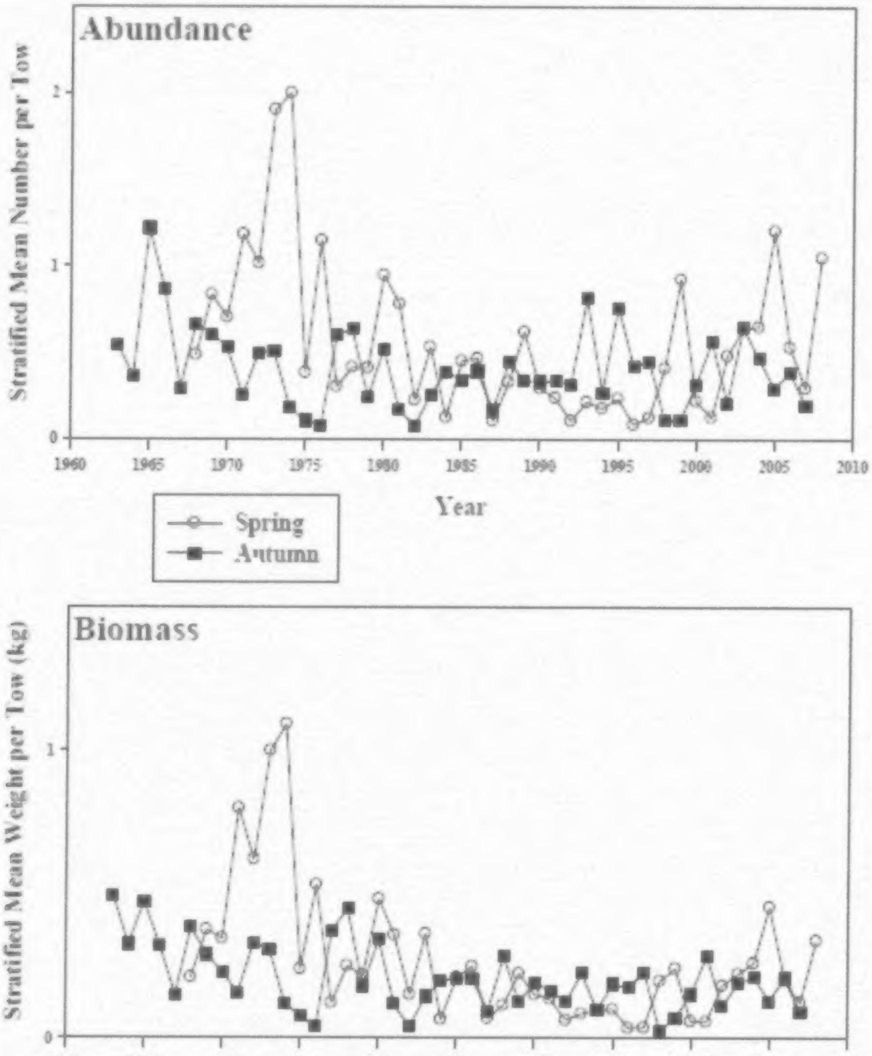


Figure 25. Abundance and biomass of Smooth Skate from the Gulf of Maine (USA) spring and fall surveys, 1963-2008.

Recruitment

The smallest sizes of fish captured in the surveys (fish less than 1 year old), provide an index of recruitment to the fished or reproductive size class. This indicates survival at the smallest sizes and potential for increase in the population in future years, depending on mortality of older juveniles. For the Scotian Shelf (Laurentian-Scotian DU), recruitment averaged higher since the 1990s than during the 1970s and 80s (Figure 26). Similar data are not available for other regions.

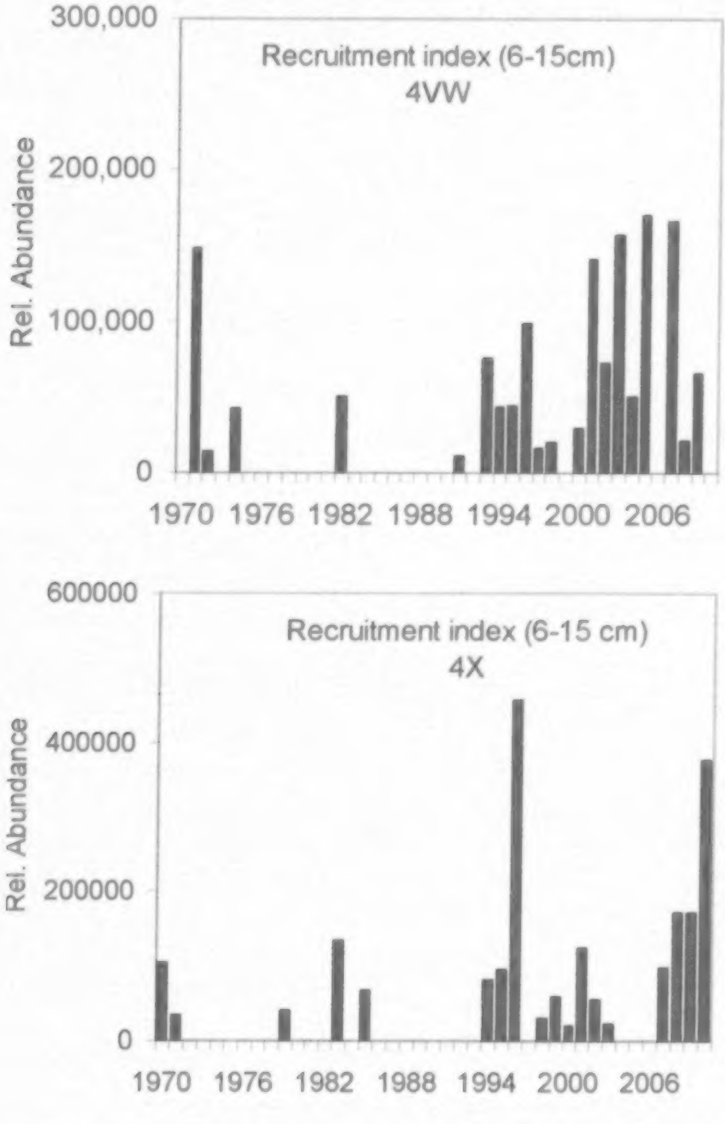


Figure 26. Abundance of fish < 15 cm, year class 0 (McPhie and Campana 2009b), an index of recruitment for the Laurentian-Scotian DU.

Rescue Effect

The extent of migration and dispersal, if any, between the western Scotian Shelf, Bay of Fundy and Georges Bank, and American waters on Georges Bank and the Gulf of Maine is unknown. However, the distribution of Smooth Skate in Canadian waters is continuous with that in American waters and on the Nose of the Grand Bank, suggesting that fish may move across the border. Rescue of the isolated Hopedale Channel and Funk Island Deep DUs is unlikely.

THREATS AND LIMITING FACTORS

Temperature

At the northernmost edge of their distribution, Hopedale Channel and Funk Island Deep DUs, Smooth Skates reach peak densities in the warmest available waters, which suggests that the species is at the coldest thermal fringe of its distribution. Survival could be affected when temperature is lower than normal, as was observed in the 1980s and 1990s (see Figure 4), especially if other threats such as excessive fishery removals were at play. However, there is no direct evidence that below-average temperatures have affected survival.

Predation

Benoît and Swain (2011) showed that in the southern Gulf of St. Lawrence, juvenile mortality has been declining since the 1970s. In contrast, adult mortality increased sharply in the 1990s and 2000s. Although fishing was implicated in the early declines, fishing pressure has been low since the early 1990s. This suggests that predation on adults may be limiting recovery of this species, with Grey Seals identified as the most likely predator (Benoît and Swain (2011).

Fishery bycatch

There are no targeted fisheries for this species, but bycatch mortality has probably played a role in declines in all four DUs. Vulnerability to exploitation and extinction risk has been documented for various elasmobranch species by Holden (1973), Roberts and Hawkins (1999), Dulvy *et al* (2000), Dulvy and Reynolds (2002), and Frisk *et al.* (2001), although not for Smooth Skate. Low reproductive potential brought about by slow growth, late sexual maturation, low fecundity, and long reproductive cycles results in low intrinsic rates of increase and low resilience to fishing mortality (Hoenig and Gruber 1990; Smith *et al.* 1998, Musick *et al.* 2000; Musick 2004; Reynolds *et al.* 2005). Although there are no directed commercial fisheries for Smooth Skate, it is taken as bycatch in fisheries targeting other species (Kulka 1986; Kulka *et al.* 2006, NOAA/NMFS 2000a, 2009).

Most captured Smooth Skates are discarded and there is some evidence that they may suffer fairly high rates of post-discard mortality (Laptikhovsky 2004; Benoît 2006). Laptikhovsky (2004) reported mortality rates of 40% or greater for other species of skates captured in trawls although no data are available for Smooth Skate. Work is ongoing in the USA to examine this issue (Sulikowski 2011).

There is considerable uncertainty about bycatch rates of Smooth Skate in many fisheries. As such, trends in removals of Smooth Skate should be viewed with caution.

NL Regions (Hopedale Channel, Funk Island Deep, Laurentian-Scotian DU)

Bycatches of Smooth Skate from Canadian fisheries were estimated using methods detailed in Kulka *et al.* (2006). An index of exploitation, relative fishing mortality or relative F (commercial catch/relative biomass), was calculated using a ratio of estimated bycatch to research survey biomass. The average annual Smooth Skate bycatch in the NL Region (encompassing the Hopedale Channel, Funk Island Deep, Flemish Cap and a portion of the Laurentian-Scotian DU) has been declining since 2002 (Figure 27). Most catches are taken in Laurentian-Scotian DU skate longline, crab pot, cod otter trawl, scallop dredge and redfish otter trawl fisheries (Kulka *et al.* 2006). Estimates of relative F averaged 2.2% for the Funk Island Deep DU and 0.9% for the Laurentian-Scotian DU (southwest Grand Banks) (Figure 27). Because the catchability to survey trawls is less than 100%, the actual exploitation rate is less than that indicated by relative F.

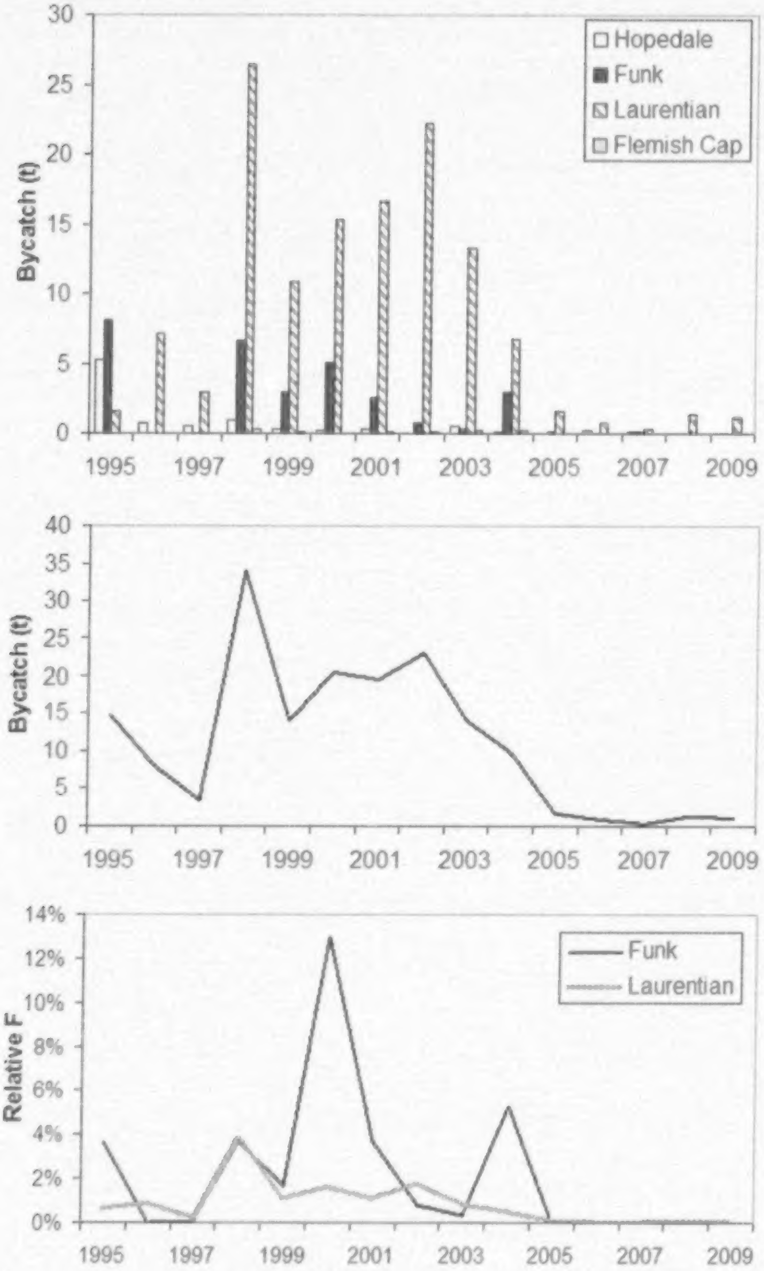


Figure 27. Estimates of bycatch removals of Smooth Skate in commercial fisheries from the Grand Banks to the Labrador Shelf. In the upper panel data were calculated for each of the DUs that occur in the NL Region jurisdiction (encompassing the Hopedale Channel, Funk Island Deep, and Grand Banks part of the Laurentian-Scotian DU). The middle panel shows these data summed, and the bottom panel shows relative fishing mortality, expressed as removals/survey biomass.

To further examine the impact of fishing on this species, changes in relative abundance were examined in relation to trawl effort for the Funk Island Deep and Laurentian-Scotian DU (NL sector). Annual maps of trawling intensity (Kulka and Pitcher 2001) were overlaid on distribution of Smooth Skate (survey number per tow). Changes in abundance within areas of intense trawling, moderate trawling and untrawled grounds were then compared. In all areas of different trawling intensity, the abundance trajectories were similar, although in Funk Island Deep untrawled areas, the decline occurred earlier (Figure 28).

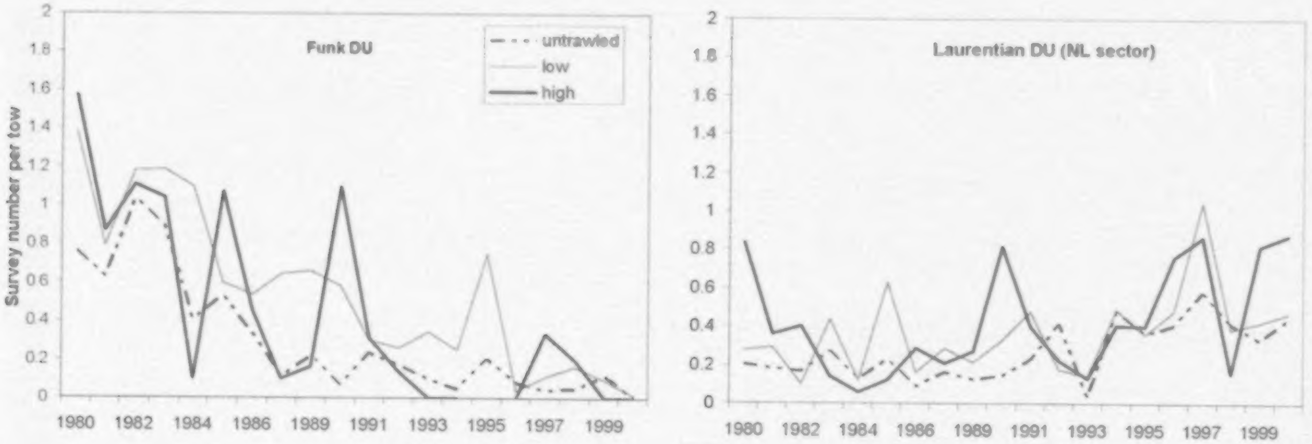


Figure 28. Change in abundance of Smooth Skate in relation to various levels of intensity of trawl effort in the Funk Island Deep DU. High refers to places where >25% of the bottom was covered by trawling, low is where 0.01-25% was trawled. Untrawled is where no trawl effort occurred in that year. Refer to Kulka and Pitcher (2001) for details.

Quebec Region (Laurentian-Scotian DU)

Estimates of bycatch of Smooth Skate are not available for the northern Gulf of St. Lawrence.

Gulf Region (Laurentian-Scotian DU)

Total bycatch removals of Smooth Skate peaked in the early 1990s at about 200 t. Bycatch has declined since, has been 100 t since the mid-1990s and is currently < 50 t/year (Figure 29).

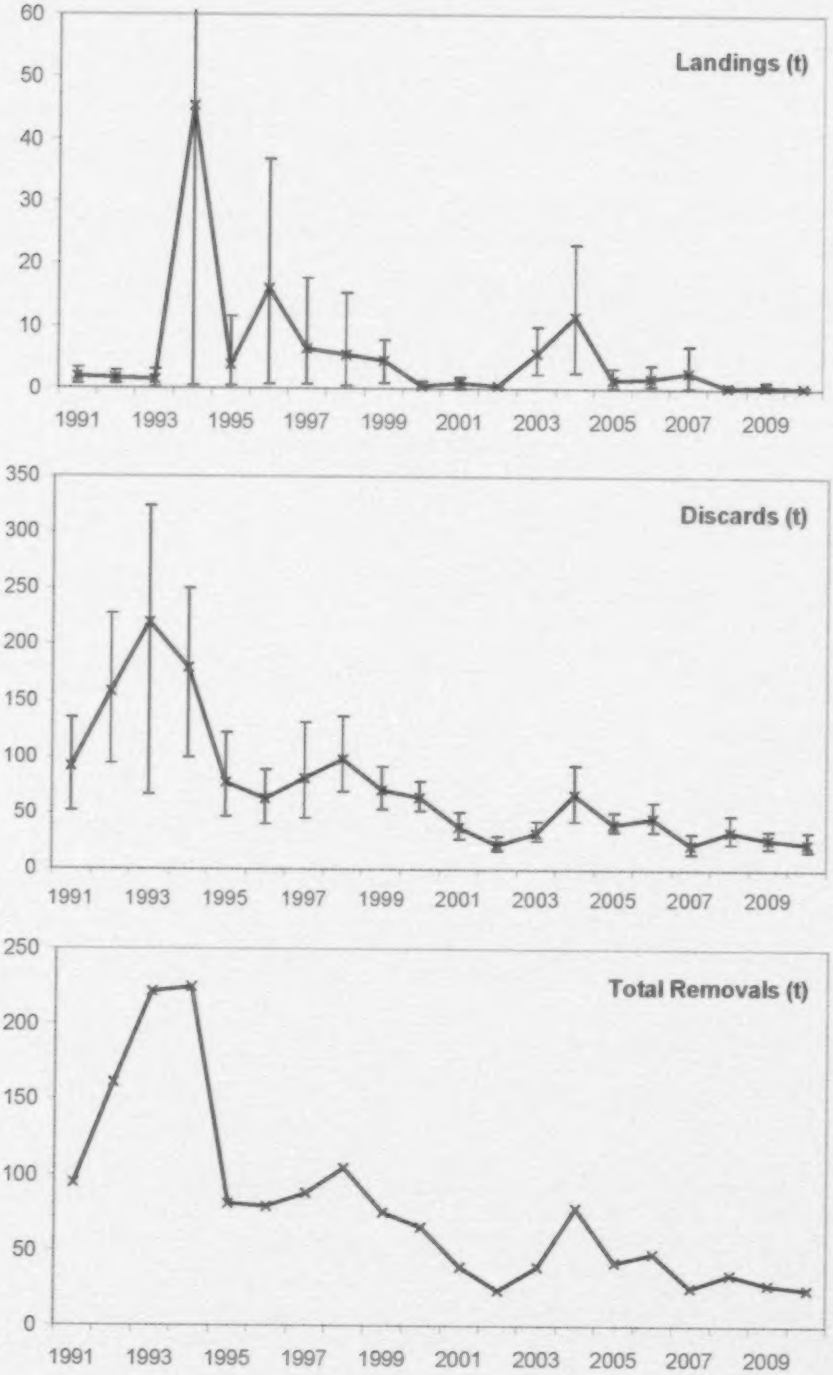


Figure 29. Landings and discards of Smooth Skate in the southern Gulf of St. Lawrence based on observer data adjusted to total landings.

Maritimes Region (Laurentian-Scotian DU)

Estimated bycatches of Smooth Skate on the Scotian Shelf decreased from over 800 t to less than 150 t since 1993 when the cod and haddock fisheries were closed, and continued to decline thereafter (Figure 30). A directed skate fishery was started in 1994 on the eastern Scotian Shelf (targeting winter and Thorny Skate) when catches of all skates totalled 2200 t but declined to 100 t by 2005. Relative fishing mortality peaked in the 1990s (at 5-7%) and is presently at low levels (Figure 31); as above, this relative fishing mortality index probably overestimates real fishing mortality.

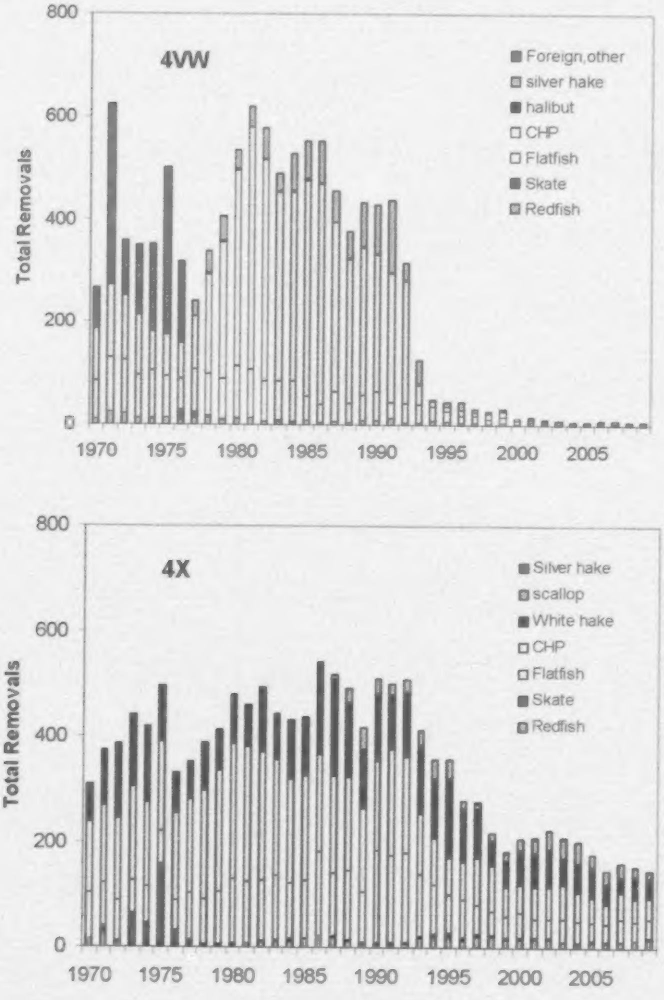
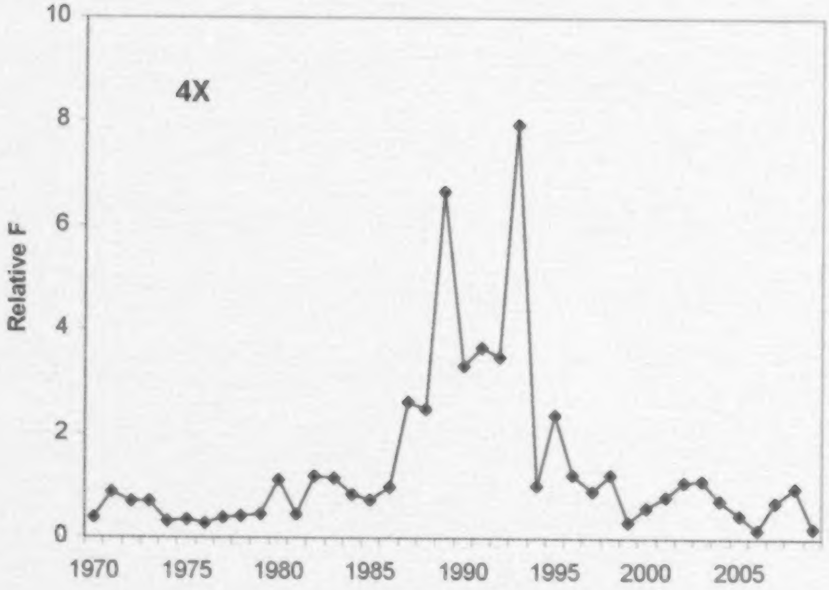


Figure 30. Estimated removals, t, of Smooth Skate from selected directed fisheries in Div. 4X and Divs. 4VsW as derived from observer reports. Observer coverage in other fisheries was insufficient to estimate removals or insignificant numbers of Smooth Skates were reported as bycatch.



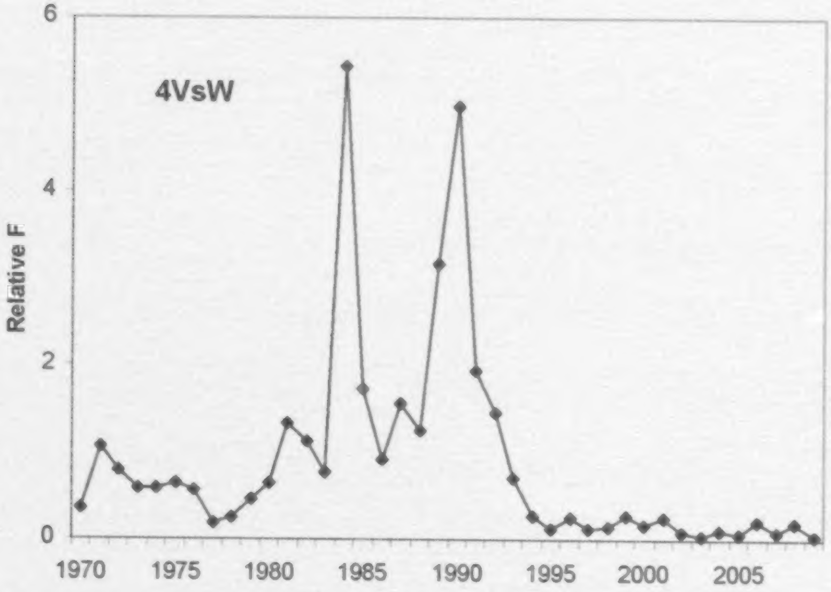


Figure 31. Relative F (relative fishing mortality) derived from the estimated removals of Smooth Skate and summer RV biomass for each NAFO subdivision.

Gulf of Maine

In the USA, recent assessments indicate that the biomass of Smooth Skate has increased above threshold levels mandated by the *Sustainable Fisheries Act* and this species is therefore no longer considered to be overfished (NOAA/NMFS USA SAW Data poor assessments 2009).

PROTECTION AND STATUS

The IUCN has listed Smooth Skate as "Endangered" on their Red List, a global assessment of risk of extinction (Sulikowski *et al.* 2010). In the United States, there is currently a ban on landing this species due to a population decline in that area. Presently, Smooth Skate are considered as "not overfished" (Miller *et al.* 2009, NOAA/NMFS 2009). Smooth Skate receive no special protection nor do they have any status designation in Canada at this time. A petition to list Smooth Skate under the US *Endangered Species Act* has been submitted recently.

A fishery for Thorny Skate is managed by the DFO through the *Fisheries Act* in Canadian waters and by NAFO in international waters. Fishery management measures applied to these fisheries include quotas, minimal mesh or hook sizes, fishing seasons and bycatch limits of other species. Smooth Skate are taken as bycatch only and are not the subject of any species-specific management measures.

The area of Smooth Skate habitat under protection remains extremely small given its widespread distribution and habitat requirements. Five small MPAs have been created in the northwest Atlantic: the Musquash Estuary (11.5 km^2), the Gully (2,364 km^2), Basin Head (9.46 km^2), Eastport (2 km^2) and Gilbert Bay (60 km^2). The following sites may also be designated as MPAs: the Manicouagan Peninsula on the north shore of the St. Lawrence Estuary, St. Ann's Bank, and an area in the St. Lawrence estuary. The Saguenay–St. Lawrence Marine Park is the only national marine conservation area within the range of the Smooth Skate. It covers an area of 1,245 km^2. Two additional closed areas which could provide protection to Smooth Skates over limited areas are the 2J Crab box and the Funk Island Deep box.

The distribution of the Smooth Skate overlaps "The Gully", a marine protected area of approximately 1000 km^2 on the outer portion of the Scotian Shelf where regulations prohibit the disturbance, damage, destruction or removal of any living marine organism. However, this area only represents a small fraction of the distribution in Canadian waters. Canada is presently considering a portion of the Laurentian Channel as a Marine Protected Area. The Channel is an area of large concentrations of Smooth Skate, particularly juveniles.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

The report writer wishes to thank Margaret Treble, Mark Simpson, Carolyn Miri, Jim Simon, Doug Swain and Brigitte Bernier for their cooperation with providing data and related background documents. Also, Jim Simon provided invaluable insight into the groundfish survey operation and James Sulikowski was a great source of information on Smooth Skate growth and reproduction biology. This report would not have been possible without the many years of service provided by ocean-going staff of Fisheries and Oceans Canada during their groundfish surveys. Funding for the preparation of this status report was provided by Environment Canada.

Authorities Consulted

Mark Simpson, Section Head, Fisheries and Oceans Canada, NL Region, St. Johns NL.

Carolyn Miri, Biologist, Fisheries and Oceans Canada, NL Region, St. Johns NL.

Brigitte Bernier, Biologist, Fisheries and Oceans Canada, Québec Region, Mont-Joli, Québec.

Doug Swain. Research Scientist, Fisheries and Oceans Canada, Gulf Region, Moncton, New Brunswick.

Jim Simon, Aquatic Biologist, Fisheries and Oceans Canada, Maritimes Region, Dartmouth, Nova Scotia.

James Sulikowski, Assistant Professor, University of New England, Biddeford, Maine, USA.

Margaret Treble, Research Scientist, Fisheries and Oceans Canada, Central and Arctic Region, Winnipeg, Manitoba.

INFORMATION SOURCES

Anon. 2003. Geomatica V. 9 Users Guide. PCI Geomatics, 50 West Wilmot St., Richmond Hill, ON.

Benoît, H.P. 2006. Estimated discards of winter skate (*Leucoraja ocellata*) in the southern Gulf of St. Lawrence, 1971-2004. CSAS Res. Doc. 2006/002.

Benoît, H.P. and D.P. Swain. 2003. Standardizing the southern Gulf of St. Lawrence bottom-trawl survey time series: adjusting for changes in research vessel, gear and survey protocol. Can. Tech. Rep. Fish. Aquat. Sci. No. 2505.

Benoît, H.P., and D.P. Swain. 2011. Changes in size-dependent mortality in the southern Gulf of St. Lawrence marine fish community. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/039. iv + 22 p

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish. Bull. U.S. Fish. Wildl. Serv. 74 (53).

Bishop, C.A. 1994. Revisions and additions to stratification schemes used during research vessel surveys in NAFO Subareas 2 and 3. NAFO SCR Doc. 94/43. 10 p.

Bourdages, H., D. Archambault, B. Morin, A. Frechet, L. Savard, F. Gregoire, and M. Berube. 2003. Preliminary results from the groundfish and shrimp multidisciplinary survey from August 2003 in the northern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2003/078.

Bowman, R.E., C.E. Stillwell, W.L. Michaels, and M.D. Grosslein. 2000. Food of Northwest Atlantic fishes and two common species of squid. NOAA Tech. Mem. NMFS-NE-155. 138 p.

Brodie, W.B. 2005. A description of the fall multispecies surveys in SA2 + Divisions 3KLMNO from 1995-2004. NAFO SCR Doc. 05/8 Serial No. N5083

Clay, D. 1991. Seasonal distribution of demersal fish (Osteichthyes) and skates (Chondrichthyes) in the southeastern Gulf of St. Lawrence. Can. Spec. Publ. Fish. Aquat. Sci. 113: 241-259.

Colbourne, E. B., J. Craig, C. Fitzpatrick, D. Senciall, P. Stead and W. Bailey. 2010. An Assessment of the physical oceanographic environment on the Newfoundland and Labrador Shelf in NAFO Subareas 2 and 3 during 2009. SCR 10/16.

Colbourne, E. B., and D. W. Kulka. 2004. A preliminary investigation of the effects of ocean climate variations on the spring distribution and abundance of Thorny Skate (*Amblyraja radiata*) in NAFO Divisions 3LNO and Subdivision 3Ps. NAFO SCR Doc. 04/29 N4978.

Cox, D.L., P. Walker, and T. J. Koob. 1999. Predation on eggs of Thorny Skate. Trans. Am. Fish. Soc. 128: 380-384.

Darbyson, E., and H.P. Benoît . 2003. An atlas of the seasonal distribution of marine fish and invertebrates in the southern Gulf of St. Lawrence. Can. Data Rep. Fish. Aquat. Sci. 1113: 294 p.

Doubleday, W.G. 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Counc. Stud. No. 2.

Dufour, R., H. Benoît, M. Castonguay, J. Chassé, L. Devine, P. Galbraith, M. Harvey, P. Larouche, S. Lessard, B. Petrie, L. Savard, C. Savenkoff, L. St-Amand and M. Starr. 2010. Ecosystem status and trends report: Estuary and Gulf of St. Lawrence ecozone. CSAS Res Doc. - 2010/030.

Dulvy, N.K., J.D. Metcalfe, L. Glanville, M.G. Pawson, and J.D. Reynolds. 2000. Fishery stability, local extinctions, and shifts in community structure in skates. Conserv. Biol. 14: 283-293.

Dulvy, N. K., and J.D. Reynolds. 2002. Predicting extinction vulnerability in skates. Conserv. Biol., 16: 440-450.

Frisk, M.G., T.J. Miller, and M.J. Fogarty. 2001. Estimation and analysis of biological parameters in elasmobranch fishes: a comparative life history study. Can. J. Fish. Aquat. Sci. 58: 969-981.

Garrison, L.P., and J.S. Link. 2000. Dietary guild structure of the fish community in the Northeast United States continental shelf ecosystem. Mar. Ecol. Prog. Ser. 202: 231-240.

González C., E. Román, X. Paz, and E. Ceballos. 2006. Feeding habits and diet overlap of skates (*Amblyraja radiata*, *A. hyperborea*, *Bathyraja spinicauda*, *Malacoraja senta* and *Rajella fyllae*) in the North Atlantic. NAFO SCR Doc. 06/53 Ser. No. N5285, 17 p.

Hoenig, J.M., and S.H. Gruber. 1990. Life-history patterns in the elasmobranchs: implications or fisheries management. In H.L. Pratt, Jr., S.H. Gruber & T. Taniuchi (eds). Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of fisheries, pp. 1–16. U.S. Department of Commerce, NOAA Tech. Rep. NMFS (National Marine Fisheries Service) 90.

Holden, M. J. 1973. Are long-term fisheries for elasmobranchs possible? Rapp. P.-V. Réun. Cons. Int. Explor. Mer 164: 360-367.

Hunter, E., A.A. Buckley, C. Stewart and J.D. Metcalfe. 2005. Migratory behaviour of the thornback ray, *Raja clavata* in the southern North Sea. J. Mar. Biol. Assoc. UK 85: 1095-1105.

Kneebone, J.D., E. Ferguson, J.A. Sulikowski, and P.C.W. Tsang. 2007. Endocrinological investigation into the reproductive cycles of two sympatric skate species, *Malacoraja senta* and *Amblyraja radiata*, in the western Gulf of Maine Environ. Biol. Fish. 80: 257–265 DOI 10.1007/s10641-007-9215-8.

Kulka, D.W. 1986. Estimates of discarding by the Newfoundland offshore fleet in 1985, with reference to trends over the past 5 years. NAFO SCR Doc. 86/95, Ser. No. N1221. 20p.

Kulka, D.W., E.M. DeBlois and D. B. Atkinson. 1996. Non-traditional groundfish species on Labrador Shelf and Grand Banks -- skate. DFO Atl. Fish. Res. Doc. 96/98. 29 p.

Kulka, D. W. 1998. SPANdex - SPANS geographic information system process manual for creation of biomass indices and distributions using potential mapping. DFO Atl. Fish. Res. Doc. 98/60 28p.

Kulka, D.W., and D.A. Pitcher. 2001. Spatial and temporal patterns in trawling activity in the Canadian Atlantic and Pacific. ICES CM 2001/R:02 57 p.

Kulka, D.W., D. Swain, M.R. Simpson, C.M. Miri, J. Simon, J. Gauthier, R. McPhie, J. Sulikowski, and L. Hamilton. 2006. Distribution, abundance, and life history of *Malacoraja senta* (*M. senta*) in Canadian Atlantic Waters. CSAS Res Doc. 2006/93.

Kulka, D.W., M.R. Simpson and C. Miri. 2007. Reproductive attributes of three exploited skate species on the Grand Banks and in surrounding Canadian waters. NAFO Reproductive Symposium Poster.

Laptikhovsky, V.V. 2004. Survival rates for rays discarded by the bottom trawl squid fishery off the Falkland Islands. Fish. Bull. 102: 757-759.

McEachran, J.D. 1973. Biology of seven species of skates (Pisces: Rajidae). Ph.D. dissertation, Coll. William and Mary, Williamsburg, VA. 127 p.

McEachran, J.D. and. J.A. Musick. 1975. Distribution and relative abundance of seven species of skates (Pisces: Rajidae) which occur between Nova Scotia and Cape Hatteras. Fish. Bull. (U.S.) 73: 110-136.

McEachran, J.D., D.F. Boesch and J.A. Musick. 1976. Food division within two sympatric species-pairs of skates (Pisces: Rajidae). Mar. Biol. 35: 301-317.

McEachran, J.D., and K.A. Dunn. 1998. Phylogenetic analysis of skates, a morphologically conservative clade of elasmobranchs (Chondrichthyes: Rajidae). Copeia 1998 (2): 271-290.

McEachran, J.D. 2002. Skates. Family Rajidae. *In* Bigelow and Schroeder's Fishes of the Gulf of Maine. 3rd Edition. *Edited by* B.B. Collette and G. Klein- MacPhee. p. 60-75. Smithsonian Institution Press, Washington, DC. 748 p.

McPhie, R. P., and S. E. Campana. 2009a. Reproductive characteristics and population decline of four species of skate (Rajidae) off the eastern coast of Canada. Journal of Fish Biology 75: 223–246. doi:10.1111/j.1095-8649.2009.02282.

McPhie, R. P., and S.E. Campana. 2009b. Bomb dating and age determination of skates (family Rajidae) off the eastern coast of Canada. – ICES Journal of Marine Science 66: 546–560.

Miller, T., R. Muller, R. O'Boyle and A. Rosenberg. 2009. Report by the Peer Review Panel for the Northeast Data Poor Stocks Working Group. Prepared for Data Poor Assessment Working Group Northeast Fisheries Science Center NOAA/NMFS, Woods Hole, MA.

Musick, J.A., G. Burgess, G. Cailliet, M. Camhi, and S. Fordham. 2000. Management of sharks and their relatives (Elasmobranchii). Fisheries 25: 9-13.

Musick, J.A. 2004. Introduction: management of sharks and their relatives (Elasmobranchii), In 'Elasmobranch Fisheries Management Techniques'. (Eds J.A. Musick and R. Bonfil), pp. 1-6. (Asia Pacific Economic Cooperation Publication. APEC#203-FS-03.2).

Natanson, L.J., J.A. Sulikowski, J.R. Kneebone and P.C. Tsang. 2007. Age and growth estimates for the Smooth Skate, *Malacoraja senta*, in the Gulf of Maine. Env. Biol. Fish. 80: 293-308.

NOAA /NMFS 2000a. Report of the 30th Northeast Regional Stock Assessment Workshop (30th SAW): Public Review Workshop. Northeast Fish. Sci. Cent. Ref. Doc. 00-04. 53 p.

NOAA/NMFS. 2009. The Northeast Data Poor Stocks Working Group Report December 8-12, 2008 Meeting Part A. Skate species complex, deep sea red crab, Atlantic wolffish, scup, and black sea bass Northeast Fisheries Science Center Reference Document 09-02a.

Packer, D.B., C.A. Zetlin and J.J. Vitaliano. 2003. Smooth Skate, *Malacoraja senta*, life history and habitat characteristics. NOAA Technical Memorandum NMFS NE 177. 26 p.

Petrie B. and R. G. Pettipas. 2010. Physical Oceanographic Conditions on the Scotian Shelf and in the eastern Gulf of Maine (NAFO areas 4V,W,X) during 2009. NAFO SCR Doc. 10/12, 22p.

Randhawa, H. S., G. W. Saunders, M. E. Scott and M. D. B. Burt. 2008. Redescription of *Pseudanthobothrium hanseni* Baer, 1956 and description of P. purtoni n. sp. (Cestoda: Tetraphyllidea) from different pairs of rajid skate hosts, with comments on the host-specificity of the genus in the northwest Atlantic. Syst Parasitol 70: 41–60. DOI 10.1007/s11230-007-9122-6.

Reynolds, J.D., N.K. Dulvy, N.B. Goodwin and J.A Hutchings. 2005. Biology of extinction risk in marine fishes. *Proceedings of the Royal Society of London* B 272, 2337-2244.

Roberts, C.M, and J.P. Hawkins 1999. Extinction risk in the sea. Trends Ecol. Evol. 14: 66, 241-245.

Siferd, T. 2010. Bycatch in the shrimp fishery from Shrimp Fishing Areas 0-3, 1979 to 2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/037. vi + 77 p.

Simon, J.E. and P.A. Comeau. 1994. Summer distribution and abundance trends of species caught on the Scotian Shelf 1970 92, by the research survey groundfish survey. Can. Tech. Rep. Fish. Aquat. Sci. 1953:x+145 p.

Simon, J.E., S. Rowe, and A. Cook. 2012. Status of Smooth Skate (*Malacoraja senta*) and Thorny Skate (*Amblyraja radiata*) in the Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/080: viii + 102 p.

Simpson, M.R., Mello, L.G.S., Miri, C.M., Treble, M., and Siferd, T. 2012. Distribution, abundance, and life history of Smooth Skate (*Malacoraja senta* Garman 1885) in Northwest Atlantic waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/116. iv + 40 p.

Smedbol, R.K., P.A. Shelton, D.P. Swain, A. Fréchet and G.A. Chouinard. 2002. Review of population structure, distribution and abundance of cod (*Gadus morhua*) in Atlantic Canada in a species-at-risk context. CSAS Res Doc. 2002/82.

Smith, S.E., D.W. Au and C. Show. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. Mar. Freshw. Res. 41: 663-678.

Sosebee K.A. 2005. Maturity of Skates in Northeast United States Waters. Journal of Northwest Atlantic Fishery Science, 35:: 141–153.

Sulak, K.J. P.D. MacWhirter, K.E. Luke, A.D. Norem, J.M. Miller, J.A. Cooper and L.E. Harris. 2009. Identification guide to skates (Family Rajidae) of the Canadian Atlantic and adjacent regions. Canadian Technical Report of Fisheries and Aquatic Sciences 2850, 46 p.

Sulikowski, J. 2011. Elasmobranch Mortality and Stress Physiology http://www.neaq.org/conservation_and_research/projects/project_pages/elasmobranch_mortality_and_stress_physiology.php

Sulikowski, J. A., W. B. Driggers III, G. W. Ingram Jr. Kneebone, D. E. Ferguson and P. C. W. Tsang. 2007a Profiling plasma steroid hormones: a non-lethal approach for the study of skate reproductive biology and its potential use in conservation management. Environ Biol Fish. DOI 10.1007/s10641-007-9257-y

Sulikowski, J.A., S. Elzey, J. Kneebone, J.A. Jurek, P.D. Danley, W.H. Howell, P.C.W. Tsang. 2007b. The reproductive cycle of the Smooth Skate, *Malacoraja senta*, in the Gulf of Maine. Marine and Freshwater Research 58, 98-103.

Sulikowski, J.A., Elzey, S., Kneebone, J., Howell, W.H., Tsang, P.C.W. 2007c. The reproductive cycle of the Smooth Skate, *Malacoraja senta*, in the Gulf of Maine. J. Mar. Fresh. Res. 58: 98-103.

Sulikowski, J. A., A. M. Cicia, J. R. Kneebone, L. J. Natanson and P. C. W. Tsang. 2009. Age and size at sexual maturity of the Smooth Skate Malacoraja senta from the western Gulf of Maine Journal of Fish Biology (2009) 75, 0–0. doi:10.1111/j.1095-8649.2009.02443.

Sulikowski, J., Kulka, D., Gedamke, T. & Barker, A. 2004. *Malacoraja senta*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.1. www.iucnredlist.org

Sulikowski, J., D.W. Kulka, T. Gedamke and A. Barker. 2010. *Malacoraja senta*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010. www.iucnredlist.org.

Swain, D.P., and Benoît, H.P. 2012. Smooth Skate (*Malacoraja senta*) in the southern Gulf of St. Lawrence: life history, and trends from 1971-2010 in abundance, distribution and potential threats. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/xxx. iv + xx p.

Swain, D.P., and A.F. Sinclair. 1994. Fish distribution and catchability: what is the appropriate measure of distribution? Can. J. Fish. Aquat. Sci. 51: 1046-1054.

Swain, D.P., T. Hurlbut and H.P. Benoît. 2006. Changes in the abundance and size of skates in the southern Gulf of St. Lawrence, 1971–2002. Journal of North. Atl. Fish. Sci. 36 (2).

Templeman, W. 1965. Rare skates of the Newfoundland and neighbouring areas. J. Fish. Res. Bd. Can. 22: 259 279.

Templeman, W. 1984. Migrations of Thorny Skate, *Raja radiata*, tagged in the Newfoundland area. J. Northw. Atl. Fish. Sci. 5: 55-64.

Tsang, P. C. W. 2005. Identification of Life History Parameters for Two Exploited Skate Species (*Amblyraja radiata* and *Malacoraja senta*) in the Gulf of Maine: Strategies for Fisheries Management. Award number: 111403 (UNH Account Number); NA16FL1324 (Grantor Number).

Walker, P.A., G. Howlett and R. Millner. 1997. Distribution, movement and stock structure of three ray species in the North Sea and eastern English Channel. ICES J. Mar. Sci. 54: 797-808.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

David Kulka, who prepared this document, is retired from Fisheries and Oceans Canada, and holds an Emeritus position and is researching elasmobranch and fishery issues. Within DFO Mr. Kulka worked on assessment of skates as NAFO designated expert and also had several roles in the area of species at risk, at various times as head of Marine Fish, Species at Risk and regional coordinator for the species at risk program. Currently, Mr. Kulka is Chair of the ICES Fish Ecology Working Group, and co-Vice Chair, northwest Atlantic, of the Elasmobranch Species Specialist Group of IUCN. He is also a member of the COSEWIC Marine Fish Species Specialist Committee. Mr. Kulka is also involved in Marine Fishery Certification. One area of expertise and research is spatial analysis, which was applied in this document.